Draft Report

Evaluation of Delta Wetlands Proposed Fish Screens, Siphons and Pumping Stations

Prepared for

Department of Water Resources' Consulting Panel on December 12, 2001

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SECTION 1.0

Introduction

1.1 Background

The Department of Water Resources (DWR), Bureau of Reclamation (USBR) and CALFED are jointly conducting feasibility level engineering, geologic, environmental, operational, economic, and other studies under the In-Delta Storage Program. The evaluations include investigations to convert Webb Tract and Bacon Island in the Sacramento-San Joaquin Delta into storage reservoirs (Delta Wetlands Project). Delta Wetlands Properties, the proponent of Delta Wetlands Project, proposed a plan that makes use of existing pumps and siphons and adding two new pump stations per island for diverting water from the Delta channels into storage reservoirs. The pumps and siphons will be located around the perimeter of the islands and will be equipped with removable drum style fish screens. As an alternative, the Department is evaluating the option of using consolidated pumping/gravity integrated facilities with flat plate continuously cleaned fish screens. URS Corporation (Contractor) evaluated the merits, impacts, and deficiencies of pump/siphon/fish screens systems as proposed by Delta Wetlands and make recommendations as to the need for the consolidated integrated facility structures on Webb Tract and Bacon Island.

1.2 Purpose and Scope

The scope of work consists of performing a study analyzing the Delta Wetlands fish screen proposal and producing a report that contains the following information:

1. List fish screen design criteria as used in the Delta Wetlands proposal.
2. Identify potential environmental impacts of Delta Wetlands proposal for existing and new pumps/siphons/fish screens facilities located on the perimeter of Webb Tract and Bacon Island (i.e. aesthetics and others).
3. Identify and discuss operation and maintenance issues associated with the proposed pump/siphon/fish screen facilities by Delta Wetlands.
4. Identify and evaluate structural issues associated with the design, construction, and operation of existing and new pumps/siphons/fish screens systems as proposed by Delta Wetlands.
5. Discuss the failure or damage potential of existing and new pump/siphon/fish screen systems as proposed by Delta Wetlands for earthquake, settlement, and flood conditions.
6. Estimate the total operation and maintenance costs for the Delta Wetlands proposal including long range costs associated with this proposal in case of structural damage or failures. The costs will be based on historical costs for similar facilities, and adjusted for this proposal.

7. Discuss the need and benefits of consolidated pump/gravity integrated facilities.

The work was conducted in accordance with all applicable standards, guidelines, terms, and conditions contained in Standard Agreement No. 4600001747. The work was limited to evaluation of existing information. The study area is shown on Plate 7.

1.3 Authorization

The work was authorized under Task Order Number IDS-1001-1747-001 under Standard Agreement Number 4600001747, dated June 30, 2001, between the State of California, Department of Water Resources, and URS Corporation.

SECTION 2.0

Project Description

The CALFED Record of Decision (ROD) has identified the In-Delta Storage Program as one of the projects to be pursued. Stage 1 of the ROD requires that feasibility studies be conducted to select and recommend a project alternative by December 2001. The ROD included an option to initiate a new project if Delta Wetlands proves cost prohibitive or infeasible.

Effectiveness of the alternatives described here will be evaluated to provide the following benefits:

- Water supply flexibility
- Export and transfer of water through the SWP and CVP system
- Improve Delta water quality
- Provide water for the Environmental Water Account (EWA)
- Facilitate maintenance of flow requirements in the Delta

Federal and State entities will acquire Delta Wetlands (DW) Project from Delta Wetlands Properties and will operate it in accordance with the terms and conditions of the Permit issued by the State Water Resources Control Board and all other permits, agreements, and limitations imposed on the Project.

Delta Wetlands Properties proposed a water storage and wetlands project utilizing four islands in the Sacramento-San Joaquin Delta (Delta). The project would involve diverting and storing water on two of the islands, Webb Tract and Bacon Island or "reservoir islands," and seasonally diverting water to create and enhance wetlands and to manage wildlife habitat on other two islands, Holland Tract and Bouldin Island or "habitat islands."

The project would primarily consist of:

- Improving and strengthening the levees of Webb Tract and Bacon Island to meet or exceed the criteria outlined in DWR Bulletin 192-82. Levee improvements would address erosion caused by wind and water waves action through placement of rock revetment on the slopes of the levees. The maximum water level in the storage reservoirs will not exceed +4 above mean sea level (MSL) providing a storage capacity of about 217 thousand acre-feet (TAF).

- Installing two new Intake Siphon Stations along the perimeter of each "reservoir island." Each Station will incorporate 16 new siphon pipes 36-inch in diameter with a combined diversion of 1375 cfs per Station (reference Table 1 of the June 25, 2001 letter from Barbara Brenner to Leslie Pierce). The rate of diversions will vary with pool elevation and water availability. The maximum rate of diversion onto either Webb Tract or Bacon Island would be 4,500 cubic feet per second (cfs) and the combined maximum daily rate of diversion onto all four islands (including diversions to habitat islands) would not exceed 9,000 cfs. The combined maximum monthly average rate of diversion would be 4,000 cfs (Figures 1 and 2), which is assumed 2000 cfs per island (1000 cfs per station)

- Installing drum-style fish screens (similar to those used in agricultural diversions) around the intake of each of the 64 new and 57 existing siphon pipes.
- Installing two new discharge pump stations on the reservoir islands. One Discharge Pump Station with 32 pumps on Webb Tract and another Discharge Pump Station with 40 pumps on Bacon Island. All discharge pipes will be 36-inch-diameter. The installed pumps will be an assortment of axial-flow and mixed-flow pumps to accommodate a variety of head conditions and flow rates throughout drawdown. Discharges would be pumped at a combined maximum daily average rate of 6,000 cfs (including discharge from the habitat islands). The combined monthly average discharge rate would not exceed 4,000 cfs.

The diversion of water onto "habitat islands" is restricted to the existing water rights held by DW and it is limited to 200 cfs (19 TAF annually). The 200 cfs amount is included in the maximum daily and monthly average rates of diversion.

SECTION 3.0

Design Criteria

3.1 Conceptual Design Drawings and Basis for Evaluation

Documented design criteria for the proposed intake and discharge facilities is limited to hydraulic, fish screen criteria, and limited operational criteria. Structural and geotechnical design criteria are not specifically addressed. However, any proposed structure will have to be designed to meet applicable building codes and engineering standards.

The conceptual design drawings are limited in detail, so comments are directed to the general details available. Details of the existing diversions proposed for screening are even less clear, but it is assumed that smaller, yet similar types of screens will be placed on those diversions. In our analysis, we have addressed the merits and deficiencies of this concept as presented. Recommendations on design improvements are made should this concept be developed further as well as suggestions for other appropriate designs. The drawings dated May 10, 2001 show details different from those in the originally submitted EIR (Figures 2-1 to 2-5). Major changes relate to the position of the booster pumps on the intake pipes and a different pumping arrangement on the discharge facility. The older EIR drawings show pumping units that floated on the surface of the interior reservoir. This concept used flexible piping to allow vertical movement of the pumping units. The revised drawings have pumping units placed on the levee surface or on pile structures above high water and have rigid pipe sections. Comments are directed to these revised drawings, except when more information is provided in the EIR drawings or as noted below.

The conceptual intake facilities include fish protection screens. These screens are similar in concept to standard cylindrical screens used on a number of pump and siphon intake installations, such as manufactured by Lakos, CTC, Intake Screens Incorporated, Hendricks, U.S. Filter, and others. The main difference between this design and similar installations is screen unit size. The largest diameter wire mesh cylindrical fish screen installed in California was made by Lakos and is 68 inches in diameter. It consisted of two screens mounted together at the end of a slant pump and is similar to the Delta Wetlands design shown. This screen, installed in 1994, has a design capacity of 40 cfs (designed for 0.33 fps) and is fitted with an automated internal backwash system. It is located on the Sacramento River near Knights Landing in a deep and swift river section. Maintenance has been minimal, although the woven wire mesh was recently replaced with perforated plates due to screen wear and damage. Large woven wire screen units made by CTC have also been installed at DWR's Horseshoe Bend site on Sherman Island (1998), but at 54-inches in diameter, the two screens deliver only 30 cfs at peak capacity using the 0.2 fps approach velocity criteria. This screen is shown on Plate 4. Like most large diameter screens installed to date, they are only removable by cranes with the assistance of underwater divers.

Other large cylindrical screens have been installed in California (and elsewhere), but most are designed using wedgewire screens and have air burst backwash systems. Larger diversions (i.e. larger than 40 cfs) typically manifold individual screen units together to achieve the higher flow rates. The periodic burst of air can lift debris if there is a strong sweeping flow to carry away debris, but it does not replace periodic manual brush cleanings by divers. The advantage of this type screen is that the screens are quite durable, if protected from heavy river debris, and do not have moving parts. The disadvantage is that the air cleaning is only marginally effective at cleaning the debris from the underside of the screens. In large river systems that carry heavy debris, these screens are more vulnerable to damage than screens along a bank and are thus usually protected by debris deflectors or protection piles. Examples of recent installations using this design include the following sites:

- DFG's Grizzly Island diversion in the Suisun Marsh (by Hendricks, four screens, each 42-inch diameter and 40 cfs each)
- M&T Ranch Intake on the Sacramento River near Chico (Cook Design, four screens, each 42-inch diameter and approximately 40 cfs each)
- Maxwell Irrigation District Intake on Sacramento River near Princeton (Cook design, three screens, each 41-inch diameter and 35 cfs each)

Although these installations use large screens, they are nowhere near the size envisioned for Delta Wetlands Project (7'– 9" in diameter and 25'-6" long). In addition, with very few exceptions, most screened diversions use some type of automated cleaner, and no commercially available screens use the end caps as part of the screen area, likely due to cleaning issues. The proposed DW screens, like the example projects above, are not "off the shelf" designs. It should be noted that experience with smaller design are available, but there is no experience with a screen of the proposed DW configuration and size.

3.2 Fish Screen Criteria

Screens are required on any new or modified diversions as required by the California Fish and Game Code. Diversions are also screened to comply with endangered species protection laws giving the diverter protection from incidental take. Both the National Marine Fisheries Service (NMFS) and the California Department of Fish and Game (DFG) have established criteria for intake screens in California (see Appendix A). These criteria address the needs of primarily juvenile anadromous salmon and steelhead trout (both are listed species). However, they are generally protective of most fish over 20 mm in length. The U.S. Fish and Wildlife does not have established fish screen criteria; however, a screen approach velocity criteria of 0.2 fps for delta smelt protection has been mandated in several biological opinions or agreed to for a number of projects in the Delta and Suisun Marsh Area (CCWD Los Vaqueros and Rock Slough Intakes, Banta Carbona ID new screen, SRCD Suisun Marsh screens, DFG's Grizzly Island Intake, DWR's Roaring River intake, City of Sacramento intake, DWR's Sherman Island screens, USBR Tracy fish test facility, etc.). Other species/lifestages have not been specifically addressed for this site, as required by the DFG fish screen criteria (DFG Screen Criteria Section 2,(B)(3)).

Approach velocity criteria is only one criterion for screening effectiveness. Siting, maintenance, operation, and channel hydraulics are equally important. The established criteria of the DFG is "general screening criteria" and is vague for Delta diversion applications (tidal areas, varied species, variable conditions) and where the diversion magnitude is significant. The NMFS criteria is specific to anadromous fish and is also vague in regards to large Delta diversion applications. These applications would be handled on a "case by case" basis in consultation. Screen "criteria" can be subject to various interpretations due to the potential increased direct and indirect impacts. Although much of the applicable criteria for screening is seemingly mandated, it is the underlying objective of fish protection that really must be applied to the intake design. With this in mind, a screen facility can be designed that may not meet all criteria, but still be considered acceptable to the fishery agencies. Accordingly, the Resource agency representatives must be involved in the design process to gain approval.

3.3 Egg and Larval Protection Criteria

Intake screens should take into account the best available technology and be protective of a variety of fish species and lifestages in addition to those of threatened or endangered status. The Delta Wetlands proposed design screens, as with most exclusion screens intend to use a 5/32-inch mesh opening. While this may keep most fish out, this mesh will not protect larval fish from being entrained. Larval fish could be an important lifestage to protect at the DW project depending on the final operating criteria and its coincidence with vulnerable lifestages in the area. There are technologies that can screen egg and larval lifestages, but they generally have extremely low approach velocities. A geotextile (fabric) barrier screen, such as the "Gunderboom," can be protective of smaller fish, but it too is unproven at such a large scale. Two installations of this design are proposed at Mirant Corporation's Pittsburg and Contra Costa Power Plant near Antioch, CA. Such installations have very low approach velocities (<0.05 fps) and extensive maintenance requirements (Steve Gallo, Mirant Corporation, Personal Communication, September 2001).

3.4 Screen Criteria Used in Delta Wetlands Proposal

The drawings list the following specifications as they relate to screening criteria:

Screen Approach Velocity (Va):

> Approximate screen area = 720 square feet
> Flow per screen = 1375 cfs/16 intakes = 86 cfs
> Va = 86/720 = 0.12 feet per second
> *[NOTE: Criteria is 0.2 fps max.]*

Screen Openings and Porosity:

> Woven wire mesh = 7x0.035 mesh -- Approximate diagonal opening = 5/32 inch
> Perforated Plate = 5/32 inch holes, no open area listed.
> *[NOTE: Criteria is 3/32 inch max. opening (measured diagonally for square openings with a 27 percent minimum open area.]*

Screen Cleaning:

Manual cleaning methods, presumably with a hand brush by diver or surface technician.

[NOTE: DFG screen criteria for screens which are not self-cleaning shall be designed with an approach velocity one-fourth that required for the screen or Va = 0.05 fps. Also, the screen shall be cleaned before the approach velocity exceeds 0.2 fps.]

Discussion:

Major areas of criteria non-compliance relate to cleaning requirements, screen mesh (and perforated plate opening size), and screen area, as discussed below:

<u>Cleaning</u>: Even with a full time cleaning maintenance staff, the screens will not be able to meet the cleaning requirement. Screens without automated cleaning devices (brushes, air, water backwash) therefore have to be sized four times greater or fitted with automatic cleaning devices. Issues and recommendations on structural features and operations and maintenance requirements are presented in other sections.

<u>Screen Mesh</u>: Screen openings have recently been reduced for the protection of steelhead trout fry. To date, there is no exemption for screens in the Delta since they could be present. Screen approach velocity is still calculated based on the gross area (less structural members), so this requirement applies to the screen only. The open area requirement of 27 percent minimum has impacts on screen material strength and cleaning. A lower open area will generally have higher strength, but correspondingly higher "through slot" velocities making cleaning more problematic. Higher open areas will generally have lower screen material strength, but fewer cleaning issues.

<u>Screen Area</u>: The screen area shown on the drawings appears to be marginally sufficient to meet the 0.2 fps approach velocity standard; however, this does not meet the requirement for manually cleaned screens. Also, for screens over 40 cfs, flow uniformity is critical. The approach velocity criteria can be interpreted as a maximum allowable velocity averaged over a small screen area, or as a "not to exceed" criteria. Regardless of the interpretation, careful attention should be placed on balancing flows throughout the screen. The designs show, in concept, an interior flow distributor. This feature has been successfully used on other screen designs to distribute flows around the screen surface. However, due to the size of these units, the screen velocity distribution should be modeled to determine how the screen and the flow baffle should be designed to achieve the flow uniformity objective. Flow uniformity is just as important for cleaning aspects as it is for fisheries protection.

3.5 Hydraulic and Structural Design Criteria

The proposed diversion must function under a wide range of hydraulic and tidal conditions. Because the pipe design is a siphon, the pipe must be "primed" to start flows. Siphoning is only possible if the net suction head is not too great to be overcome. Lowering the pipe crest, by boring through the levee can reduce the suction head requirement, but it appears that the arrangement shown will work. Flow can be in either direction depending on water elevations on either side of the pipe, or may be regulated by a valve or in-line pump. Siphons have the advantage of being shut off by introducing air into the pipe or by closing a gate as long as the pipe ends are submerged to prevent having to prime each time the pipes must flow. Air entrainment could be problematic at the proposed hinge, despite a proposed gasket, since the hinge appears to be located frequently above the water line. Air entrainment could also be damaging to the in-line pump if it should continue to operate without water due a siphon “break.”

Tidal currents in this area of the Delta can force flows in both directions at approximately up to 3 fps past the intakes. Water surface fluctuations can vary over 10 feet due to tides, atmospheric conditions, and Delta outflow. Water surfaces elevations on the storage islands will also vary. Depending on the head availability, various pipe flows may result by gravity only (siphon), by “boosting” the gravity flow by an in-line pump, or by pumps only. As calculated above, each diversion may operate at up to 86 cfs per diversion pipe and screen.

There are no details on the size or design of the in-line pump station. If 86 cfs must be delivered at any given available head, the pump could be a significant feature. If the pump is assumed to only be used to slightly augment gravity flows, then its design could be minimized. Regardless of its size, the in-line pump station will add to the pipe headlosses unless operated during diversions. We are not aware of any in-line pump stations used on siphon pipes on Delta diversions.

Flow monitoring systems are not shown, but should be provided. Meters could be used to monitor flow compliance, operate booster pumps, and/or to detect hydraulic problems or performance over time.

Average pipe velocity at the maximum flow through the proposed 36-inch diameter intake is in excess of 12 fps. This velocity is high and above those generally used in pipelines when headloss, interior pipe erosion, and pipe stability is of concern. A more common velocity limitation would be around 10 fps. A larger diameter pipe or two pipes should be considered to reduce velocities, lower energy costs on the in-line pump station, reduce damage to the pipe interior, and reduce scour potential at the pipe outfall.

As noted earlier, hydraulic performance of the screen units is very important to both screen function and fisheries protection. Considering the number of units proposed (64 new large screens), modeling of the screen unit will likely be required by the fisheries agencies approving the project. Modeling should focus on the maximum size unit (diameter and length) that can be developed with good hydraulic control. Hydraulic performance on screens over 40 cfs are likely to be given more scrutiny by fisheries agencies simply due to their size.

The screen siting can be important for hydraulics as well. A good rule of thumb for both hydraulic performance and sediment issues is to provide a minimum clearance between channel bottom and fish screen invert is ½ diameter. A similar submergence criteria is usually warranted. Therefore, the proposed screen should be located in at least 16 feet of water depth (at low water).

3.6 Design Compared to Intent of Criteria

The basic intake design concept is unproven on such a large scale. The combined intake capacity of both Webb Tract and Bacon Island is approximately 9000 cfs (average daily), or approximately equal to the combined diversion of the existing State and Federal water projects in the South Delta. Basic fish screen design does not mean that only approach velocity criteria are met. The concentration of fish drawn to the intake area and given little or no "escape" area must be addressed. If the intake flows create a sump or "bathtub drain" effect in this area of the Delta, simply keeping fish out of the intake with an exclusionary screen is only part of the issue. Screened intakes that create a sump condition are generally fitted with fish collection systems such as at the SWP and CVP fish facilities in the South Delta. Scenarios operated with the tides could lessen the need for collection systems, but this is not being addressed in this initial assessment.

SECTION 4.0

Potential Environmental Impacts

The proposed project will impact both the aquatic and landside environments. Aquatic impacts, as noted in Section 3.0, can be both directly and indirectly assessed. Indirect effects due to how this project impacts flows and fish distributions throughout the Delta are not addressed in detail here. Direct impacts can be measured in terms of impingement, entrainment, and localized predation losses due to the facility.

Good fish screens should minimize the impingement and entrainment losses since they are based on conservative criteria. Very small fish that have limited or no swimming abilities could be susceptible to losses. Operations plans could be developed to limit exposure of these impacts.The Final Operations Criteria mentioned in the Biological Opinion requires on-island monitoring to detect incidental entrainment of eggs, larvae and juveniles from January through August. The regulatory agencies require monetary compensation for the take of those life stages depending on the density and species.

4.1 Predation Issues

The four new intake facilities would combine to make one of the largest full physical exclusion screens in the world. Screen systems of this magnitude require additional considerations due to the concentration of potential fishery activity at one location. A large concentration of individual screen units should not be evaluated on the performance of the individual screens, but instead as a system operating in its environment. The present configuration may draw more water than will sweep past the intakes at some times. During peak diversion, flows will be drawn from the surrounding channels and directed predominantly into the diversion screens. These conditions occur during peak high slack water periods and could last for several hours. Fish may be drawn progressively into this “dead end” area, creating a high concentration of juvenile and larval fishes that may be drifting in response to the flow. Increased predator opportunities may result which must be considered into the overall efficiency of the facility. At the SWP's J. E. Skinner Fish Protective Facility, for instance, it has been determined that predation is one of the most significant losses at the facility. At the Tracy Fish Facility, predators are regularly removed to limit losses. Predatory fish may be able to take advantage of the DW intake facility's structures and hydraulic flow inconsistencies and prey on the concentrations of smaller fishes in the area. Smaller fish may be trapped and concentrated in this area due to the lack of bypass past the screens. Facilities also have limited cover for small fish, while larger fish can hold in these areas better and get their prey quicker.

While the fish screens and support piles are potential predator havens, other waterway obstacles, such as boat dock facilities can provide predator habitat. DFG and NMFS have typically assumed some predation losses associated with fish screen facilities, such as a 15 percent prescreen direct loss due to the Tracy Fish Facility.

4.2 Site Impacts

Site impacts can occur both during construction and due to long term operation. Construction impacts are typically limited and can usually be mitigated. The temporary and long term loss of habitat are generally related to the facility footprint. For this project, the land-side of the levees will be reconstructed and disturbed regardless of the facility construction, so additional screen footprint impacts on the land-side will be minimal. The construction impact area is therefore primarily on the levees’ water side area.

Temporary impacts can also occur during construction activities. These impacts can include potential habitat and riparian vegetation losses disturbed during construction; noise impacts, such as from pile driving, on fisheries and birds (Swainsons Hawk nesting, Burrowing Owls, etc.); water quality degradation from possible dredging or river bed disturbances; and potential river bed impacts from rock protection, structure placements, or dredging operations.

Long term impacts will be related to the permanent losses of riparian vegetation (such as from additional rock protection), maintenance activities, access improvements, visual impairments, pump noise, recreation, and project lighting.

Maintenance around the intake and discharge facilities will be routine and will necessitate the need for access. Barge and/or truck mounted cranes will use these roads that will also be used for other purposes such as levee inspection. The intake and discharge station areas will have to be cleared periodically to visually inspect (and prime) the pipes and pumps. The fish screens will typically be accessed from the water as currently proposed. Dredging activities should be limited, and only performed if there is excessive sediment deposition beneath the screens that limit their function.

The fish screen and discharge facilities consist primarily of piled structures and pumps that will be visible most of the time. The area will also be fitted with safety features to warn boaters of the underwater structures and hazards. This may consist of additional lighting, floating booms, and buoys. When the fish screens are in the raised position, the visual impacts will be evident as all screens will be above the water surface. Noise impacts from the pump operations will vary according to proposed operations.

The operation and existence of the fish screens will pose a number of recreational impacts. Boat wakes should be limited to minimize structural damage, so speed reductions could limit current recreational activities in the area. The waterway will also be constricted due to the loss of waterway use occupied by the fish screens. Maintenance activities, especially when the barge mounted crane is operational, will further limit activities in the area.

Due to fluctuating water surfaces in the reservoir, it is not anticipated that there will be long term impacts due to the intake or discharge areas beyond those of the reservoir operations.

SECTION 5.0

Operation and Maintenance Issues

5.1 General

Operations and maintenance costs are too often overlooked or minimized, but experience has demonstrated that these issues cannot be overlooked. Because capital costs for screen facilities can range from $2000 to $20,000 per cfs, it is often desirable to look for cost cutting features. Material selection, cleaning systems, retrieval systems, structural engineering review, safety features, and site work can drive costs quickly. Standardized or "off the shelf" technologies have their place, but they must be carefully reviewed for their applicability at each site. A number of small screens have failed because of unanticipated loads and harsh riverine conditions. Experience gained from several small screen failures has helped improve designs and helped designers plan appropriate screen and protection systems, including proper material selection and cleaning systems. Most failures have been the result of poorly designed cleaning systems, were subjected to severe debris loads, or because maintenance schedules and inspections were not adhered to. To date, most failures have occurred on smaller cylindrical screens attached to pump intakes or siphon pipes.

Cylindrical screens have the advantage of being adaptable to a number of pump or pipe installations with minimal cost. Heavy site work is generally limited since most of the facility rests on driven piles instead of on engineered foundations. The main disadvantage is that these systems are generally difficult to access from the shoreline. Those that are accessible use a retrievable design as shown on Plate 5. Hinged screen systems are not truly retrievable since access to the screens is still limited from the shoreline (unless walkways are provided). Screen designs that are not retrievable are rarely inspected due to the added hassles and expense of inspections. Inspections on non-retrievable units are usually performed by divers, but underwater cameras can be used if water clarity is sufficient. This makes detecting or preventing problems difficult which can lead to total screen structural failures without warning. These screens are also often left in place during flood conditions and are susceptible to damage and shorter structure life.

Failed screen installations, such as the Butte Creek Farms screen and the Andreotti Farms screen units (Plates 2 and 8) have since been replaced with redesigned screens. The new screens feature a number of improvements including the following:

- Automatic cleaners using brushes instead of water or air;
- Wedgewire screens in lieu of woven wire mesh;
- Retrievable screen systems using tracks for inspections and removal when not in use;
- Monitoring systems to shut off pumps and alert operators of problems;
- Corrosion resistant materials, such as stainless steel for all parts;
- Better flow balanced screens;
- Easy access for repairs and inspection; and
- Structurally designed for greater hydrostatic loads and impacts.

The additional cost of improved screens has been on the order of two to four times the original installation cost of the cheaper systems.

The proposed Delta Wetlands screen design has very few of these functional features. Specifically, the proposed design will be difficult and expensive to operate and maintain for the following reasons:

- No automatic screen cleaning system
- Poorly retrievable system, even when raised, it will still be subject to corrosion, and poor access for inspection
- No monitoring system
- Poor access to the screen
- Dissimilar metals on pipe and screen
- Woven wire screen (stainless steel is good but not resistant to biofouling)
- Appears to be structually inadequate as described above

To improve the design of this system, a significant redesign will be necessary without incurring a significant risk of failure. Some of the mentioned O&M issues are described below in more detail.

5.2 Debris Management

Debris management can be the most significant maintenance issue and pose the greatest risk factor to the system operation. A cumulative effect could occur during periods of maximum diversion due to poor sweeping flows through the area. Sweeping flows are important in shearing debris off the screens and carrying it away. If debris is not carried away, it must be removed from the system, not simply brushed aside only to be swept back on the screen. Clean screens are important to efficient diversion operations (reduces head losses) and to reduce fish injury (due to reduction in high velocity “hot spots” caused by poor flow uniformity). Clean screens and flow uniformity are both necessary criteria issues. DFG requires screens to be capable of being “continuously” cleaned at up to five minute intervals. It further stipulates that unless this requirement is met, screen area should be increased four-fold. Lifting screens out of the water for periodic cleaning will not satisfy this criterion.

5.3 Screen Retrievability

As noted earlier, lifting screens out of the water when they are not in service may extend the service life of the screen unit and improve inspection. The use of a hinge in lieu of other methods however, still limits access unless access is provided via a walkway or boat. A hinge will also not remove the screen from its corrosive environment being just above the water. A barge-mounted crane is assumed to lift these screens and to lower them in the water. This operation will take the assistance of a boat crew and divers to raise each of the screen units for inspection and cleaning. Based on experience from DWR Operations personnel on Sherman Island screen maintenance, it may only be possible to inspect and clean four units per day. With one crew, it could take 16 days to complete inspections on just the new large screen units, or once every three weeks.

DWR experience on the Sherman Island screens and on Bacon Island has shown that hinged designs are problematic (Plate 1). If the screen is left in the open position (hinged up), the large cylinder screens will be subject to movement with the waves. This can cause fatigue and high stresses. Lateral support from a hinge design is also poor. The mass of the screen could cause excessive stresses on the pipe hinge and subject the system to additional damage.

Fatigue will also limit the service life of the screen and hinge if the screen is not completely removed from the water. Considerations could be given to manifolding two or more smaller screens together to reduce structural and foundation stresses.

Corrosion is another item frequently overlooked, but can drastically shorten the service life of screens in corrosive environments such as the Delta. The proposed DW design does not show any cathotic protection system such as anodes. The design does specify stainless steel, but only for some screen materials. The final design will need to consider the corrosion of the entire system, not just the screens. For instance, screen mesh laid over plain or even coated steel can be subject to corrosion due to galvanic action caused by dissimilar metals. Screen mesh has had to be replaced at both Horseshoe Bend (Plate 4) and at Pelgar-Mutual’s fish screen due to this. Larger screen installations, including those at Roaring River in the Suisun Marsh, use expensive deep well anode systems to protect the metals. Coatings can also be effective if protected from potential surface nicks and abrasions.

SECTION 6.0

Structural/Geotechnical Issues

6.1 General

In this section, the geotechnical and structural issues associated with the design, construction and operation of existing and new pumps/siphons/fish screens systems as proposed by Delta Wetlands (DW) are identified and evaluated. The main geotechnical issues that will have an effect on the structural components of the existing and new pumps/siphons/fish screens systems include settlement, stability, seismic loading, and erosion of the levee embankments and foundations.

The evaluation in this section is based on the conceptual-level Figures 5 to 9, dated May 10, 2001. It is recognized that these figures are conceptual and are not intended to show details sufficient for analysis. The evaluation that follows identifies and evaluates issues, and potential mitigation measures are briefly discussed that would need to be considered in succeeding design phases.

6.2 Siphons/Fish Screens

The plan view of the siphons is shown on Figure 5. Figure 6 shows an intake siphon unit in plan and elevation. The fish screen design is shown on Figure 7.

<u>Settlement:</u> The siphons are shown to be supported on the slough side of the levees by piles. The siphons on the crest and reservoir side are shown to be founded directly on the levee embankment. Additional fill will be placed on the crest and reservoir side of the levee embankments to raise them to the design crest elevation and configuration. Such additional fill will cause the levees to settle; such settlement would cause distress in the 36-inch diameter siphon pipe. Pipe bends at the levee crest would become overstressed and are subject to breaks. The effects of settlement on the siphons can be mitigated by providing flexible connections at critical points, such as at the crest of the levee. The design of flexible connection would need to be based on the anticipated settlement. The siphon pipes would need to be periodically returned to their original elevations if the settlement approaches the limits of the movement that could be accommodated by the flexible connections. The use of ball-joint ductile pipe, while expensive, should be considered for this application.

<u>Levee Stability:</u> The levees are subject to slope failure, especially during times of flooding. Slope failure would disrupt and damage the siphons. Mitigation of slope failures would require site specific assessments of slope stability at the siphon locations, and flattening of levee slopes, or use of toe drains, where there is a need to improve slope stability to meet criteria.

Pipe Stress from Excessive Velocity and Thrust: Pipe velocities may exceed 12 fps at design flows of up to 86 cfs. Pipe velocities are typically designed to be much lower than this (rule of thumb is 10 fps or lower), for pipelines of this diameter, generally due to excessive head losses in the pipes. Interior wear in the pipe can accelerate with the increase abrasive forces. The proposed pipe bends will be subject to thrust loads due to the change in momentum. No thrust blocks or restrained joint systems are shown in these areas.

Fish Screen Structure: Fish screen units are subject to a variety of loading conditions that include rising and falling of tides, wave action, head loss through the fish screens, and operational loads when the screens are lifted from the slough for cleaning. The fish screens are shown to be 25.5 feet long and 7.75 feet in diameter. The conceptual design shown on Figure 7 indicates that the fish screens may not be structurally sound. The structural members consist of 16 screen supports attached to a 3.5 foot long support ring that is attached to the siphon pipe. Details such as the dimensions of the screen supports and support ring are not shown. Conservatively, these supports should be designed for full hydrostatic head, all dead loads from the screen, and also for lateral and wave loads.

Hydrostatic head can be the greatest of these forces since they can cause collapse upon debris clogging, a common mode of failure. In the past several years, several cylindrical screens have imploded (i.e. collapsed due to excessive head) on the Sacramento River (Plates 2 and 8). If full head is not designed into the internal screen supports, a "blow-out" plug can be installed to relive excessive and damaging pressures. This plug would be designed to be sucked into the fish screens to reduce the head loss if the head were to exceed a pre-determined threshold level. Plugs would need to be monitored and replaced upon failure to prevent unscreened diversions. Once the design loads have been established, the screens would be designed to meet the loading demands.

This screen type is similar to those indicated in Section 3.1. A better screen mesh alternative is a structural panel of profile bar or wedge wire material. Wedge wire can be very rigid and withstand much higher loads than woven wire over backing bars. This material, however, can significantly add to the overall screen weight (and add to facility loads).

Plates 1, 2, 3, 4, and 8 show a woven wire screen design. Plates 5 and 6 show a cylindrical screen with wedge wire material. Collapsing screen failures have been experienced on woven wire designs (Plates 2 and 8), but failures have rarely occurred on wedge wire cylindrical screens.

Wave action can cause cyclic loading of the screens and siphons and cause additional stresses, especially to the hinge points. Hinges have been utilized on pipes supporting screens on both DWR's Sherman Island fish screens, and a previous screen on Bacon Island (Plate 1). The screen hinges have failed on both installations (Hayes and Whitlock personal communication, 2001). One way to reduce lateral cyclic loading on the fish screens and siphons is to locate a receiving cradle fixture for the siphon pipe on the supporting cross member between the two piles shown on Figure 6. This feature has been a part of several larger fish screen designs, such as at DWR's Horseshoe Bend site, and the Pelgar-Mutual fish screen on the Sacramento River. Unlike the proposed Delta Wetlands screens, both of those screens do not have hinged systems due to their excessive weight and are therefore not easily removable.

The screens are shown to be lifted when not in use. Retrievable capability is a desirable feature to increase the screen life and facilitate maintenance. A lifting eye is shown located immediately at the screens, but the hoist/lifting mechanism is not shown or described. It is assumed that the hoisting may be done by crane that is periodically mobilized to lift the screens. Alternatively, the screens may be lifted by a winch and lever arm or by an overhead crane located above the screens. The latter method would require a frame structure on piles above the screen and should be accessible by bridge from the levee crest. A winch and cable system attached to a lever arm could also be used, but the stresses from such a system would be significant and likely infeasible due to the loads on such a system. A screen system installed on Bacon Island in 1992 had such a system, but it failed structurally within two years (Plate 1).

To reduce the cyclic loading and vibration on a hinged system, the screens could be retrieved via a rail system as shown on Plate 5, or lifted vertically by a fixed hoist. For the latter, hydraulic cylinders could be used similar to what is used to hoist radial gates for spillways. The cylinders would be operated from a frame above the screens.

6.3 Discharge Pumps

The plan view of the pump stations is shown on Figure 8. Figure 9 shows a discharge pump unit in plan and elevation.

Settlement and Stability: The 36-inch diameter discharge pipe lines are shown to be supported on structural frames on the reservoir side and the pipes rest on the crest and slough side of the levee embankment. The settlement and stability issues for the siphons/fish screens discussed above, and their mitigation, also apply to the discharge pump systems. Settlement of the levee embankment can cause distress in the pipeline at the joints on both sides of the levee crest shown on Figure 9.

Erosion: The discharge end of the pipe shown on Figure 9 is located directly above the riprap on the slough side of the levees. For a discharge rate of about 94 cfs per pump, the discharge velocity would be about 13 fps through the 36-inch diameter pipe. The exit velocity would be reduced by the expansions shown on Figure 9. The riprap would have to be sized to be stable on the slough slopes due to the exit velocities from the discharge pipes and from wave action in the sloughs.

SECTION 7.0

Failure or Damage Potential

7.1 General

A risk analysis was conducted as part of the In-Delta Pre-Feasibility study addressing the seismic, flood, and operational risks. The estimated recurrence of these events and the estimated vulnerability of the DW proposed project is described below:

7.2 Damage Potential from Operation

The reservoir-side slope will be a well-compacted embankment with a wider cross-section than the existing levee and flatter slopes. The slopes on the slough side are hence more vulnerable to failure. The probability of slope failure on the slough side was estimated to be on the order of 3 percent and 8 percent in the next 40 years for Bacon Island and Webb Tract, respectively. The potential instability on the slough side results from steeper slopes and potential internal piping and erosion from high reservoir head. The probability of a slough-side slope failure leading to a breach of the embankment and uncontrolled release is much smaller. Failures on the sough side slopes could cause overstressing loads on the siphon and pipes that straddle the embankment. Ongoing consolidation could cause further deformation and differential settlement of the pipes. The operational risk of levee failure will be, however, smaller compared to the seismic and flood risks.

7.3 Damage Potential from Seismic Events

The results of seismic vulnerability study indicate that there is about 5.5 percent chance in 50 years that Bacon Island levees will fail during future earthquakes. The corresponding probability of failure for the Webb Tract levees is about 8.5 percent in 50 years. Webb Tract levee foundation has a higher susceptibility to liquefaction than does Bacon Island. The potential embankment failure modes, as they relate to the pumps, siphons, fish screen, and pipes, could include liquefaction, lateral spreading, slumping and slope failure. Liquefaction and loss of foundation support can affect the siphon unit supporting the expansion chamber on the reservoir side. The embankment slumping, deformations, and lateral spreading may cause overstressing of the 36-inch siphons and pipelines. The truss frame supporting the pumps on the reservoir side may experience strong ground shaking and deformation. The pile foundation and structure need to be designed for such shaking and associated ground deformation.

7.4 Damage Potential from Flood Events

The risk of overtopping due to flooding addressed here include the static flood stage, wind set-up and wave run-up. The data for the 100-year flood were obtained from the 1998 Long Term Levee Rehabilitation Plan by CALFED. The greatest flood overtopping depth is expected to occur at Webb Tract from Station 70+00 to 220+00 (the section opposite to Frank's Tract). Other sections at Webb Tract are also expected to overtop during the 100-year flood event. Results show that eight levee sections at Bacon Island are expected to overtop during the 100-year flood event. For all sections that would be overtopped, the probabilities of overtopping failure during the 100-year flood events were estimated to be 39 percent in a 50 year life cycle. The expected damage during flood related overtopping is the potential levee breach and scour of the reservoir island floor. The worst case scenario is when the reservoir is empty, which corresponds to a period from September to February. Scour holes have been reported to be as deep as 50 feet during historic inward levee breaches in the Delta. In the case of such failure, and if this takes place at the proposed location of pumps and siphons, severe damage to these facilities would be expected.

SECTION 8.0

Operation and Maintenance Costs

There is relatively little experience with the long term maintenance and operation costs of large screen systems using the proposed cylindrical screens. Costs that are incurred after construction are not always operations and maintenance costs but instead corrections for design deficiencies. The costs associated with the recent screen collapses at Butte Creek Farms for instance should be attributed to poor design, rather than to O&M. Similarly, DWR has experienced high maintenance costs on the Horseshoe Bend and other Sherman Island fish screens due to design changes and cleaning system failures.

Many larger screen systems in California are of the on-river vertical plate fish screen design. These screens which include RD108 (830 cfs), GCID (3000 cfs), Princeton Cordura-Glenn (600 cfs), Anderson Cottonwood Irrigation District (450 cfs), and RD1004 (240 cfs) have only recently been completed (since 1998). True maintenance costs for these installations have been minimal, and typically performed by District personnel who maintain the pump stations and perform routine dredging operations. These Districts have not staffed up to maintain or operate the screens, although it is estimated that for these screens, between $40,000 and $150,000 may go towards screen related operations and maintenance.

Large cylindrical screen installations may be subject to more intense O&M however primarily due to access and screen removal issues. The proposed Delta Wetlands design will require the use of a fully equipped barge with crane and screen storage space. These screens will not be able to be lifted from shore. As estimated earlier, it could take three weeks to simply inspect and clean the screens even if they are used only once during this period. Assuming this is sufficient (and it is likely not), the crew could consist of two tug operators, a crane operator, two divers, and a deck hand for a total of 6 people. Working 270 days per year at say $5000/day (probably low), approximately $1.4 million will be needed just for cleaning and inspection. Routine maintenance should also include anode replacement, screen repairs.

Costs due to pump station operation (other than the additional costs due to screen headloss), siphon priming, erosion, and pipe maintenance that are not related to the screens should not be included in the screen operational and maintenance costs — these costs will occur regardless of the screen.

Since the proposed DW design does not include sufficient provisions for screen cleaning, it is difficult to estimate cleaning costs when it is unlikely that this method of cleaning will be acceptable. The estimated annual O&M cost of $2.1 million by Delta Wetlands may not be sufficient to meet agency requirements just on cleaning.

SECTION 9.0

Need and Benefits of Consolidated Facilities

The proposed Delta Wetlands intake system consists of 64 new intakes with pipelines, pumps, screens, and structures, as well as 57 retrofitted intakes with screens and structures. The applicability of this concept is unproven at this scale and may necessitate smaller and more manageable facilities. However, structural and hydraulic considerations should not be the only criteria modified as described above. Functional cylindrical intake screens should be designed based on lessons learned from other installations and failures. The lessons learned from the poor performance or failure of those facilities could prevent costly mistakes and redesigned facilities for the Delta Wetlands project.

Downsizing each diversion may result in a more manageable size, say to 40 cfs, for a screen unit. Therefore, the number and complexity of the intake pipes and facilities will increase four-fold, or to approximately 248 new diversion structures and pipelines. For this concept, it would be recommended that each of these screens be designed and equipped with automatic cleaning systems, retrievable screen systems, cathodic protection, wedgewire screens, monitoring systems, and able to withstand higher structural loads and pressures. The resulting redesigned cylindrical screens may be manageable on an individual level, but unmanageable when considered as a whole.

Consolidated diversion facilities looking at different intake types may offer a better solution. Engineered, flat plate screened diversions along river banks have proven to be highly reliable under a wide variety of flows and conditions, including for those in the Delta. Examples of facilities utilizing this concept include Contra Costa Water Districts new Los Vaqueros Intake Screen (250 cfs), Reclamation District 108's new fish screen (830 cfs), and Glenn Colusa Irrigation District's new fish screen (3000 cfs). All concepts are similar and all have functioned well with very low and easy maintenance.

SECTION 10.0

Conclusions and Recommendations

Designing major fish screen intakes for the Delta Wetlands Project must include considerations related to fisheries protection; structural, hydraulic, and geotechnical design; and operations and maintenance. Successful fish screen projects depend on proper consideration of all of these factors. The proposed design does not appear to satisfy these objectives and is, therefore, deficient or a very risky design. Besides initial capital costs, future design efforts should also consider the level of operations and maintenance that will be required for the intake facility. Consolidated facilities using flat plate screen technologies appear to show promise for this application.

SECTION 11.0
References

CALFED, 1998. Levee Rehabilitation Study, August.

DWR Bulletin 192-82.

Appendix A

Appendix A

Attachment 1:

STATE OF CALIFORNIA
RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

FISH SCREENING CRITERIA
June 19, 2000

1. **STRUCTURE PLACEMENT**

   A. **Streams And Rivers (flowing water):** The screen face shall be parallel to the flow and adjacent bankline (water's edge), with the screen face at or streamward of a line defined by the annual low-flow water's edge.

   The upstream and downstream transitions to the screen structure shall be designed and constructed to match the bankline, minimizing eddies upstream of, in front of, and downstream of, the screen.

   Where feasible, this "on-stream" fish screen structure placement is preferred by the California Department of Fish and Game.

   B. **In Canals (flowing water):** The screen structure shall be located as close to the river source as practical, in an effort to minimize the approach channel length and the fish return bypass length. This "in canal" fish screen location shall only be used where an "on-stream" screen design is not feasible. This situation is most common at existing diversion dams with headgate structures.

   The current National Marine Fisheries Service - Southwest Region criteria for these types of installations shall be used (Attachment A).

   C. **Small Pumped Diversions:** Small pumped diversions (less than 40 cubic-feet per second) which are screened using "manufactured, self-contained" screens shall conform to the National Marine Fisheries Service - Southwest Region criteria (Attachment A).

   D. **Non-Flowing Waters (tidal areas, lakes and reservoirs):** The preferred location for the diversion intake structure shall be offshore, in deep water, to minimize fish contact with the diversion. Other configurations will be considered as exceptions to the screening criteria as described in Section 5.F. below.

2. APPROACH VELOCITY (Local velocity component perpendicular to the screen face

A. **Flow Uniformity:** The design of the screen shall distribute the approach velocity uniformly across the face of the screen. Provisions shall be made in the design of the screen to allow for adjustment of flow patterns. The intent is to ensure uniform flow distribution through the entire face of the screen as it is constructed and operated.

B. **B. Self-Cleaning Screens:** The design approach velocity shall not exceed:

   1. Streams and Rivers (flowing waters) - Either:

      a. 0.33 feet per second, where exposure to the fish screen shall not exceed fifteen minutes, or

      b. 0.40 feet per second, for small (less than 40 cubic-feet per second) pumped diversions using "manufactured, self-contained" screens.

   2. In Canals (flowing waters) - 0.40 feet per second, with a bypass entrance located every one-minute of travel time along the screen face.

   3. Non-Flowing Waters (tidal areas, lakes and reservoirs) - The specific screen approach velocity shall be determined for each installation, based on the species and life stage of fish being protected. Velocities which exceed those described above will require a variance to these criteria (see Section 5.F. below).

C. (Note: At this time, the U.S. Fish and Wildlife Service has selected a 0.2 feet per second approach velocity for use in waters where the Delta smelt is found. Thus, fish screens in the Sacramento-San Joaquin Estuary should use this criterion for design purposes.)

D. **C. Screens Which Are Not Self-Cleaning:** The screens shall be designed with an approach velocity one-fourth that outlined in Section B. above. The screen shall be cleaned before the approach velocity exceeds the criteria described in Section B.

E. **Frequency Of Cleaning:** Fish screens shall be cleaned as frequently as necessary to prevent flow impedance and violation of the approach velocity criteria. A cleaning cycle once every 5 minutes is deemed to meet this standard.

F. **Screen Area Calculation:** The required wetted screen area (square feet), excluding the area affected by structural components, is calculated by dividing the **maximum** diverted flow (cubic-feet per second) by the allowable approach velocity (feet per second).

   Example: **1.0 cubic-feet per second / 0.33 feet per second = 3.0 square feet**

   Unless otherwise specifically agreed to, this calculation shall be done at the **minimum** stream stage.

3. SWEEPING VELOCITY (Velocity component parallel to screen face)

A. **In Streams And Rivers:** The sweeping velocity should be at least two times the allowable approach velocity.

B. **In Canals:** The sweeping velocity shall exceed the allowable approach velocity. Experience has shown that sweeping velocities of 2.0 feet per second (or greater) are preferable.

C. **Design Considerations:** Screen faces shall be designed flush with any adjacent screen bay piers or walls, to allow an unimpeded flow of water parallel to the screen face.

4. SCREEN OPENINGS

A. **Porosity:** The screen surface shall have a minimum open area of 27 percent. We recommend the maximum possible open area consistent with the availability of appropriate material, and structural design considerations.

The use of open areas less than 40 percent shall include consideration of increasing the screen surface area, to reduce slot velocities, assisting in both fish protection and screen cleaning.

B. **Round Openings:** Round openings in the screening shall not exceed 3.96mm (5/32in). In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 2.38mm (3/32in).

C. **Square Openings:** Square openings in screening shall not exceed 3.96mm (5/32in) measured diagonally. In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 2.38mm (3/32in) measured diagonally.

D. **Slotted Openings:** Slotted openings shall not exceed 2.38mm (3/32in) in width. In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 1.75mm (0.0689in).

5. SCREEN CONSTRUCTION

A. **Material Selection:** Screens may be constructed of any rigid material, perforated, woven, or slotted that provides water passage while physically excluding fish. The largest possible screen open area which is consistent with other project requirements should be used. Reducing the screen slot velocity is desirable both to protect fish and to ease cleaning requirements. Care should be taken to avoid the use of materials with sharp edges or projections which could harm fish.

B. **Corrosion and Fouling Protection:** Stainless steel or other corrosion-resistant material is the screen material recommended to reduce clogging due to corrosion. The use of both active and passive corrosion protection systems should be considered.
Consideration should be given to anti-fouling material choices, to reduce biological fouling problems. Care should be taken not to use materials deemed deleterious to fish and other wildlife.

C. **Project Review and Approval:** Plans and design calculations, which show that all the applicable screening criteria have been met, shall be provided to the Department before written approval can be granted by the appropriate Regional Manager.

The approval shall be documented in writing to the project sponsor, with copies to both the Deputy Director, Habitat Conservation Division and the Deputy Director, Wildlife and Inland Fisheries Division. Such approval may include a requirement for post-construction evaluation, monitoring and reporting.

D. **Assurances:** All fish screens constructed after the effective date of these criteria shall be designed and constructed to satisfy the current criteria. Owners of existing screens, approved by the Department prior to the effective date of these criteria, shall not be required to upgrade their facilities to satisfy the current criteria unless:

1. The controlling screen components deteriorate and require replacement (i.e., change the opening size or opening orientation when the screen panels or rotary drum screen coverings need replacing),
2. Relocation, modification or reconstruction (i.e., a change of screen alignment or an increase in the intake size to satisfy diversion requirements) of the intake facilities, or
3. The owner proposes to increase the rate of diversion which would result in violation of the criteria without additional modifications.

E. **Supplemental Criteria:** Supplemental criteria may be issued by the Department for a project, to accommodate new fish screening technology or to address species-specific or site-specific circumstances.

F. **Variances:** Written variances to these criteria may be granted with the approval of the appropriate Regional Manager and concurrence from both the Deputy Director, Habitat Conservation Division and the Deputy Director, Wildlife and Inland Fisheries Division. At a minimum, the rationale for the variance must be described and justified in the request.

Evaluation and monitoring may be required as a condition of any variance, to ensure that the requested variance does not result in a reduced level of protection for the aquatic resources.

It is the responsibility of the project sponsor to obtain the most current version of the appropriate fish screen criteria. Project sponsors should contact the Department of Fish and Game, the National Marine Fisheries Service (for projects in marine and anadromous waters) and the U.S. Fish and Wildlife Service (for projects in anadromous and fresh waters) for guidance.

Copies of the current criteria are available from the Department of Fish and Game through the appropriate Regional office, which should be the first point of contact for any fish screening project.

Northern California and North Coast Region; 601 Locust Street, Redding, CA 96001 - (916) 225-2300.

Sacramento Valley and Central Sierra Region; 1701 Nimbus Drive, Rancho Cordova, CA 95670 - (916) 358-2900.

Central Coast Region; 7329 Silverado Trail/P.O. Box 46, Yountville, CA 94599 - (707) 944-5500.

San Joaquin Valley-Southern Sierra Region; 1234 E. Shaw Avenue, Fresno, CA 93710 - (209) 243-4005.

South Coast Region; 4649 View Crest Avenue, San Diego, CA 92123 - (619) 467-4201.

Eastern Sierra and Inland Deserts Region; 4775 Bird Farms Road, Chino Hills, CA 91709 - (909) 597-9823.

Marine Region; 20 Lower Ragsdale Drive, #100, Monterey, CA 93940 - (831) 649-2870.

Technical assistance can be obtained directly from the Habitat Conservation Division; 1416 Ninth Street, Sacramento, CA 95814 - (916) 653-1070.

The current National Marine Fisheries Service criteria are available from their Southwest Region; 777 Sonoma Avenue, Room 325, Santa Rosa, CA 95402 - (707) 575-6050.

Attachment 2:

National Marine Fisheries Service
Southwest Region
Fish Screening Criteria for
Anadromous Salmonids
January 1997

Fish Screening Criteria for Anadromous Salmonids [1]
National Marine Fisheries Service
Southwest Region
January 1997

Table of Contents

I. General Considerations

This document provides guidelines and criteria for functional designs of downstream migrant fish passage facilities at hydroelectric, irrigation, and other water withdrawal projects. It is promulgated by the National Marine Fisheries Service (NMFS), Southwest Region as a result of its authority and responsibility for prescribing fishways under the Endangered Species Act (ESA), the Federal Power Act, administered by the Federal Energy Regulatory Commission (FERC), and the Fish and Wildlife Coordination Act (FWCA), administered by the U.S. Fish & Wildlife Service.

The guidelines and criteria are general in nature. There may be cases where site constraints or extenuating circumstances dictate a waiver or modification of one or more of these criteria. Conversely, where there is an opportunity to protect fish, site-specific criteria may be added. Variances from established criteria will be considered on a project-by-project basis.

The swimming ability of fish is a primary consideration in designing a fish screen facility. Research shows that swimming ability varies depending on multiple factors relating to fish physiology, biology, and the aquatic environment. These factors include: species, physiological development, duration of swimming time required, behavioral aspects, physical condition, water quality, temperature, lighting conditions, and many others. Since conditions affecting swimming ability are variable and complex, screen criteria must be expressed in general terms and the specifics of any screen design must address on-site conditions.

NMFS may require project sponsors to investigate site-specific variables critical to the fish screen system design. This investigation may include fish behavioral response to hydraulic conditions, weather conditions (ice, wind, flooding, etc.), river stage-discharge relationships, seasonal operations, sediment and debris problems, resident fish populations, potential for creating predation opportunity, and other pertinent information. The size of salmonids present at a potential screen site usually is not known, and can change from year-to-year based on flow and temperature conditions. Thus, adequate data to describe the size-time relationship requires substantial sampling over a number of years. NMFS will normally assume that fry-sized salmonids are present at all sites unless adequate biological investigation proves otherwise. The burden of proof is the responsibility of the owner of the screen facility.

New facilities which propose to utilize unproven fish protection technology frequently require:

1. Development of a biological basis for the concept;
2. Demonstration of favorable behavioral responses in a laboratory setting;
3. An acceptable plan for evaluating the prototype installation;
4. An acceptable alternate plan should the prototype not adequately protect fish. Additional information can be found in *Experimental Fish Guidance Devices*, position statement of the National Marine Fisheries Service, Southwest Region, January 1994.

Striped Bass, Herring, Shad, Cyprinids, and other anadromous fish species may have eggs and/or very small fry which are moved with any water current (tides, streamflows, etc.). Installations where these species are present may require individual evaluation of the proposed project using more conservative screening requirements. In instances where state or local regulatory agencies require more stringent screen criteria to protect species other than salmonids, NMFS will generally defer to the more conservative criteria.

General screen criteria and procedural guidelines are provided below. Specific exceptions to these criteria occur in the design of small screen systems (less than 40 cubic feet per second) and certain small pump intakes. These exceptions are listed in Section K, Modified Criteria for Small Screens, and in the separate addendum entitled: Juvenile Fish Screen Criteria For Pump Intakes, National Marine Fisheries Service, Portland, Oregon, May 9, 1996.

II. General Procedural Guidelines

For projects where NMFS has jurisdiction, such as FERC license applications and ESA consultations, a functional design must be developed as part of the application or consultation. These designs must reflect NMFS design criteria and be acceptable to NMFS. Acceptable designs typically define type, location, method of operation, and other important characteristics of the fish screen facility. Design drawings should show structural dimensions in plan, elevation, and cross-sectional views, along with important component details. Hydraulic information should include: hydraulic capacity, expected water surface elevations, and flows through various areas of the structures. Documentation of relevant hydrologic information is required. Types of materials must be identified where they will directly affect fish. A plan for operations and maintenance procedures should be included (i.e., preventive and corrective maintenance procedures, inspections and reporting requirements, maintenance logs, etc.) particularly with respect to debris, screen cleaning, and sedimentation issues. The final detailed design shall be based on the functional design, unless changes are agreed to by NMFS.

All juvenile passage facilities shall be designed to function properly through the full range of hydraulic conditions expected at a particular project site during fish migration periods, and shall account for debris and sedimentation conditions which may occur.

III. Screen Criteria for Juvenile Salmonids

A. Structure Placement

1. General:

   The screened intake shall be designed to withdraw water from the most appropriate elevation, considering juvenile fish attraction, appropriate water temperature control downstream or a combination thereof. The design must accommodate the expected range of water surface elevations.

   For on-river screens, it is preferable to keep the fish in the main channel rather than put them through intermediate screen bypasses. NMFS decides whether to require intermediate bypasses for on-river, straight profile screens by considering the biological and hydraulic conditions existing at each individual project site.

2. Streams and Rivers:

   Where physically practical, the screen shall be constructed at the diversion entrance. The screen face should be generally parallel to river flow and aligned with the adjacent bankline. A smooth transition between the bankline and the screen structure is important to minimize eddies and undesirable flow patterns in the vicinity of the screen. If trash racks are used, sufficient hydraulic gradient is required to route juvenile fish from between the trashrack and screens to safety. Physical factors that may preclude screen construction at the diversion entrance include excess river gradient, potential for damage by large debris, and potential for heavy sedimentation. Large stream-side installations may require intermediate bypasses along the screen face to prevent excessive exposure time. The need for intermediate bypasses shall be decided on a case-by-case basis.

3. Canals:

   Where installation of fish screens at the diversion entrance is undesirable or impractical, the screens may be installed at a suitable location downstream of the canal entrance. All screens downstream of the diversion entrance shall provide an effective juvenile bypass system- designed to collect juvenile fish and safely transport them back to the river with minimum delay. The angle of the screen to flow should be adequate to effectively guide fish to the bypass. Juvenile bypass systems are part of the overall screen system and must be accepted by NMFS.

4. Lakes, Reservoirs, and Tidal Areas:

   a. Where possible, intakes should be located off shore to minimize fish contact with the facility. Water velocity from any direction toward the screen shall not exceed the allowable approach velocity. Where possible, locate intakes where sufficient sweeping velocity exists. This minimizes sediment accumulation in and around the screen, facilitates debris removal, and encourages fish movement away from the screen face.

   b. If a screened intake is used to route fish past a dam, the intake shall be designed to withdraw water from the most appropriate elevation in order to provide the best juvenile fish attraction to the bypass channel as well as to achieve appropriate water temperature control downstream. The entire range of forebay fluctuations shall be accommodated by the design, unless otherwise approved by NMFS.

B. Approach Velocity

Definition: *Approach Velocity* is the water velocity vector component perpendicular to the screen face.

Approach velocity shall be measured approximately three inches in front of the screen surface.

1. Fry Criteria - less than 2.36 inches {60 millimeters (mm)} in length.

   If a biological justification cannot demonstrate the absence of fry-sized salmonids in the vicinity of the screen, fry will be assumed present and the following criteria apply:

   Design approach velocity shall not exceed-

   Streams and Rivers: 0.33 feet per second

   Canals: 0.40 feet per second

   Lakes, Reservoirs, Tidal: 0.33 feet per second (salmonids) [(2)]

2. Fingerling Criteria - 2.36 inches {60 mm} and longer

   If biological justification can demonstrate the absence of fry-sized salmonids in the vicinity of the screen, the following criteria apply:

   Design approach velocity shall not exceed -

   All locations: 0.8 feet per second

3. The *total submerged screen area required* (excluding area of structural components) is calculated by dividing the maximum diverted flow by the allowable approach velocity. (Also see Section K, Modified Criteria for Small Screens, part 1).

4. The screen design must provide for uniform flow distribution over the surface of the screen, thereby minimizing approach velocity. This may be accomplished by providing adjustable porosity control on the downstream side of the screens, unless it can be shown unequivocally (such as with a physical hydraulic model study) that localized areas of high velocity can be avoided at all flows.

C. Sweeping Velocity

Definition: *Sweeping Velocity* is the water velocity vector component parallel and adjacent to the screen face.

1. Sweeping Velocity shall be greater than approach velocity. For canal installations, this is accomplished by angling screen face less than 45 relative to flow (see Section K, Modified Criteria for Small Screens). This angle may be dictated by specific canal geometry, or hydraulic and sediment conditions.

D. Screen Face Material

1. Fry criteria

   If a biological justification cannot demonstrate the absence of fry-sized salmonids in the vicinity of the screen, fry will be assumed present and the following criteria apply for screen material:

   a. Perforated plate: screen openings shall not exceed 3/32 inches (2.38 mm), measured in diameter.

   b. Profile bar: screen openings shall not exceed 0.0689 inches (1.75 mm) in width.

   c. Woven wire: screen openings shall not exceed 3/32 inches (2.38 mm), measured diagonally. (e.g.: 6-14 mesh)

   d. Screen material shall provide a minimum of 27 percent open area.

2. Fingerling Criteria

   If biological justification can demonstrate the absence of fry-sized salmonids in the vicinity of the screen, the following criteria apply for screen material:

   a. Perforated plate: Screen openings shall not exceed 1/4 inch (6.35 mm) in diameter.

   b. Profile bar: screen openings shall not exceed 1/4 inch (6.35 mm) in width

   c. Woven wire: Screen openings shall not exceed 1/4 inch (6.35 mm) in the narrow direction

   d. Screen material shall provide a minimum of 40 percent open area.

3. The screen material shall be corrosion resistant and sufficiently durable to maintain a smooth and uniform surface with long term use.

E. Civil Works and Structural Features

1. The face of all screen surfaces shall be placed flush with any adjacent screen bay, pier noses, and walls, allowing fish unimpeded movement parallel to the screen face and ready access to bypass routes.

2. Structural features shall be provided to protect the integrity of the fish screens from large debris. Trash racks, log booms, sediment sluices, or other measures may be needed. A reliable on-going preventive maintenance and repair program is necessary to ensure facilities are kept free of debris and the screen mesh, seals, drive units, and other components are functioning correctly.

3. Screens located in canals - surfaces shall be constructed at an angle to the approaching flow, with the downstream end terminating at the bypass system entrance.

4. The civil works design shall attempt to eliminate undesirable hydraulic effects (e.g.- eddies, stagnant flow zones) that may delay or injure fish, or provide predator opportunities. Upstream training wall(s), or some acceptable variation thereof, shall be utilized to control hydraulic conditions and define the angle of flow to the screen face. Large facilities may require hydraulic monitoring to identify and correct areas of concern.

F. Juvenile Bypass System Layout

Juvenile bypass systems are water channels which transport juvenile fish from the face of a screen to a relatively safe location in the main migratory route of the river or stream. Juvenile bypass systems are necessary for screens located in canals because anadromous fish must be routed back to their main migratory route. For other screen locations and configurations, NMFS accepts the option which, in its judgement, provides the highest degree of fish protection given existing site and project constraints.

1. The screen and bypass shall work in tandem to move out-migrating salmonids (including adults) to the bypass outfall with minimum injury or delay. Bypass entrance(s) shall be designed such that out-migrants can easily locate and enter them. Screens installed in canal diversions shall be constructed with the downstream end of the screen terminating at a bypass entrance. Multiple bypass entrances (intermediate bypasses) shall be employed if the sweeping velocity will not move fish to the bypass within 60 seconds [(3)] assuming the fish are transported at this velocity. Exceptions will be made for sites without satisfactory hydraulic conditions, or for screens built on river banks with satisfactory river conditions.

2. All components of the bypass system, from entrance to outfall, shall be of sufficient hydraulic capacity to minimize the potential for debris blockage.

3. To improve bypass collection efficiency for a single bank of vertically oriented screens, a bypass training wall may be located at an angle to the screens.

4. In cases where insufficient flow is available to satisfy hydraulic requirements at the main bypass entrance(s), a *secondary screen* may be required. Located in the main screen's bypass channel, a secondary screen allows the prescribed bypass flow to be used to effectively attract fish into the bypass entrance(s) while allowing all but a reduced residual bypass flow to be routed back (by pump or gravity) for the primary diversion use. The residual bypass flow (not passing through the secondary screen) then conveys fish to the bypass outfall location or other destination.

5. Access is required at locations in the bypass system where debris accumulation may occur.

6. The screen civil works floor shall allow fish to be routed to the river safely in the event the canal is dewatered. This may entail a sumped drain with a small gate and drain pipe, or similar provisions.

G. Bypass Entrance

1. Each bypass entrance shall be provided with independent flow control, acceptable to NMFS.

2. Bypass entrance velocity must equal or exceed the maximum velocity vector resultant along the screen, upstream of the entrance. A gradual and efficient acceleration into the bypass is required to minimize delay of out-migrants.

3. Ambient lighting conditions are required from the bypass entrance to the bypass flow control.

4. The bypass entrance must extend from floor to water surface.

H. Bypass Conduit Design

1. Smooth interior pipe surfaces and conduit joints shall be required to minimize turbulence, debris accumulation, and the risk of injury to juvenile fish. Surface smoothness must be acceptable to the NMFS.
2. Fish shall not free-fall within a confined shaft in a bypass system.
3. Fish shall not be pumped within the bypass system.
4. Pressure in the bypass pipe shall be equal to or above atmospheric pressure.
5. Extreme bends shall be avoided in the pipe layout to avoid excessive physical contact between small fish and hard surfaces and to minimize debris clogging. Bypass pipe centerline radius of curvature (R/D) shall be 5 or greater. Greater R/D may be required for supercritical velocities.
6. Bypass pipes or open channels shall be designed to minimize debris clogging and sediment deposition and to facilitate cleaning. Pipe diameter shall be 24 inches (0.610 m) or greater and pipe velocity shall be 2.0 fps (0.610 mps) or greater, unless otherwise approved by NMFS. (See *Modified Criteria for Small Screens*) for the entire operational range.
7. No closure valves are allowed within bypass pipes.
8. Depth of flow in a bypass conduit shall be 0.75 ft. (0.23 m) or greater, unless otherwise authorized by NMFS (See Modified Criteria for Small Screens).
9. Bypass system sampling stations shall not impair normal operation of the screen facility.
10. No hydraulic jumps should exist within the bypass system.

I. Bypass Outfall

1. Ambient river velocities at bypass outfalls should be greater than 4.0 fps (1.2 mps), or as close as obtainable.
2. Bypass outfalls shall be located and designed to minimize avian and aquatic predation in areas free of eddies, reverse flow, or known predator habitat.
3. Bypass outfalls shall be located where there is sufficient depth (depending on the impact velocity and quantity of bypass flow) to avoid fish injuries at all river and bypass flows.
4. Impact velocity (including vertical and horizontal components) shall not exceed 25.0 fps (7.6 mps).

5. Bypass outfall discharges shall be designed to avoid adult attraction or jumping injuries.

J. Operations and Maintenance

1. Fish Screens shall be automatically cleaned as frequently as necessary to prevent accumulation of debris. The cleaning system and protocol must be effective, reliable, and satisfactory to NMFS. Proven cleaning technologies are preferred.

2. Open channel intakes shall include a trash rack in the screen facility design which shall be kept free of debris. In certain cases, a satisfactory profile bar screen design can substitute for a trash rack.

3. The head differential to trigger screen cleaning for intermittent type systems shall be a maximum of 0.1 feet (.03 m), unless otherwise agreed to by NMFS.

4. The completed screen and bypass facility shall be made available for inspection by NMFS, to verify compliance with design and operational criteria.

5. Screen and bypass facilities shall be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved.

K. Modified Criteria for Small Screens (Diversion Flow less than 40 cfs)

The following criteria vary from the standard screen criteria listed above. These criteria specifically apply to lower flow, surface-oriented screens (e.g.- small rotating drum screens). Forty cfs is the approximate cut off; however, some smaller diversions may be required to apply the general criteria listed above, while some larger diversions may be allowed to use the "small screen" criteria below. NMFS will decide on a case-by-case basis depending on site constraints.

1. The required screen area is a function of the approach velocity listed in Section B, Approach Velocity, Parts 1, 2, and 3 above. Note that "maximum" refers to the greatest flow diverted, not necessarily the water right.

2. Screen Orientation:

   a. For screen lengths six feet or less, screen orientation may be angled perpendicular to the flow.

   b. For screen lengths greater than six feet, screen-to-flow angle must be less than 45 degrees. (See Section C Sweeping Velocity, part 1).

   c. For drum screens, design submergence shall be 75 percent of drum diameter. Submergence shall not exceed 85 percent, nor be less than 65 percent of drum diameter.

   d. Minimum bypass pipe diameter shall be 10 in (25.4 cm), unless otherwise approved by NMFS.

e. Minimum pipe depth is 1.8 in (4.6 cm) and is controlled by designing the pipe gradient for minimum bypass flow.

Questions concerning this document can be directed to NMFS Hydraulic Engineering Staff at:

National Marine Fisheries Service
Southwest Region
777 Sonoma Ave. Room 325
Santa Rosa, CA 95402
Phone: 707-575-6050

Adopted,
Date: February 24, 1997

Authorizing Signature:

1. Adapted from NMFS, Northwest Region

2. Other species may require different approach velocity standards, e.g.- in California, the U.S. Fish & Wildlife Service requires 0.2 fps approach velocity where delta smelt are present in the tidal areas of the San Francisco Bay estuary.

3. In California, 60 second exposure time applies to screens in canals, using a 0.4 fps approach velocity. Where more conservative approach velocities are used, longer exposure times may be approved on a case-by-case basis, and exceptions to established criteria shall be treated as variances.

Appendix B

Appendix B: Plates 1 – 8

IN-DELTA STORAGE PROGRAM

Draft Report - 11/26/2001

Evaluation of Delta Wetlands Proposed Fish Screens, Siphons and Pumping Stations

Plate 1 – Removal of Bacon Island fish screen (20 cfs total) due to hinge failure after two years of service. This screen was raised by hand winch from shore when it was not in use. Screen design (Lakos Plum Creek) used phosphor-bronze (anti-fouling) woven wire mesh, and was cleaned with internal backwash system. Pipe shown is 16-inch diameter.

Plate 2 – Removal of Butte Creek Farms screen (Yuba City Steel - 5 cfs) following structural collapse/failure. Cleaning system problems, excessive debris buildup, and screen unit not designed for full head contributed to failure.

Plate 3 – Severe screen mesh clogging due to internal cleaning system failure on DWR's Horseshoe Bend fish screen. Internal screen frame did not collapse/fail despite clogging.

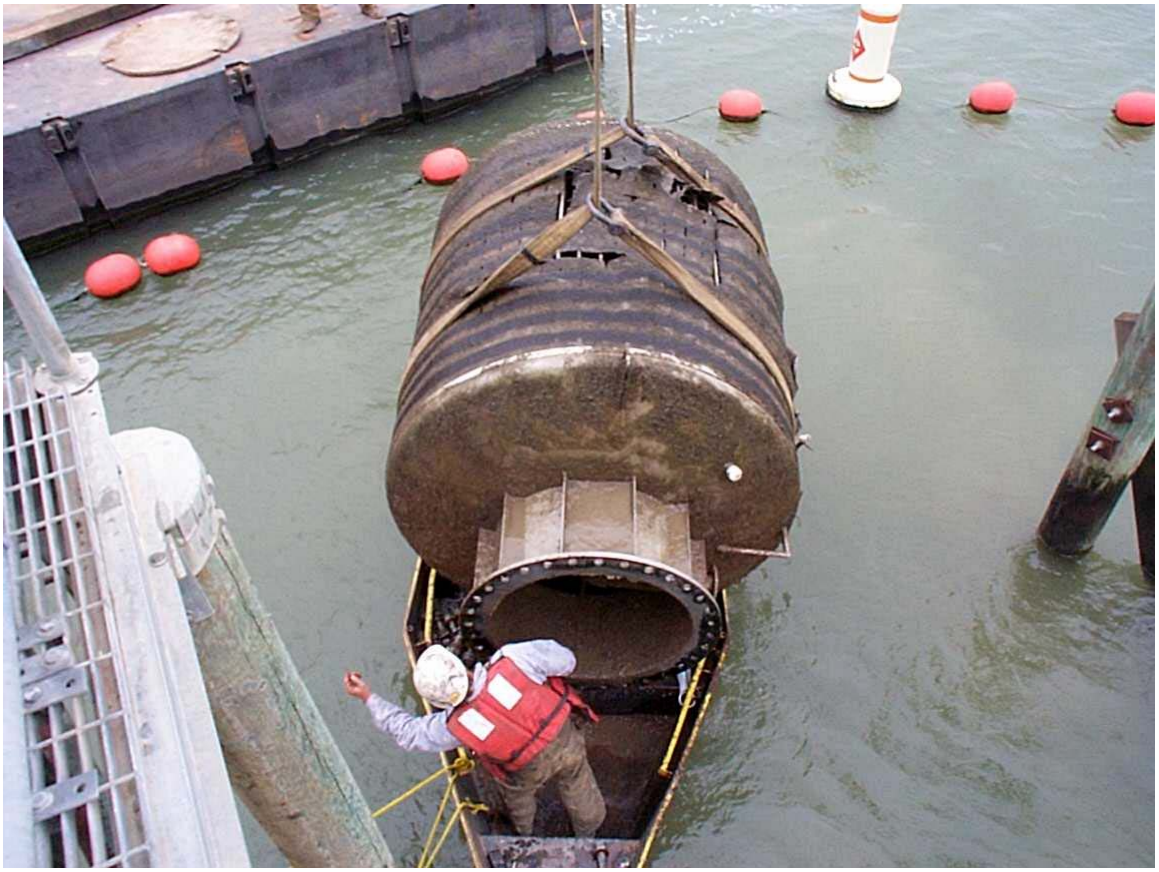


Plate 4 – Removal of DWR's Horseshoe Bend fish screen in Delta (CTC Design – 15 cfs). Screen mesh failure due to corrosion (dissimilar metals). Also note poor screen cleaning from internal backwash system

Plate 5 – Retrievable fish screen design by Intake Screens Incorporated (15 cfs total) using rails and winch system. Screen rotates slowly underwater and is automatically brush cleaned. Screen is completely removed from water when not in use.

Plate 6 – Wedgewire screen panel adds strength to screen design. Internal flow distributor/baffle, automatic brush cleaning system, and corrosion resistant features reduce maintenance.

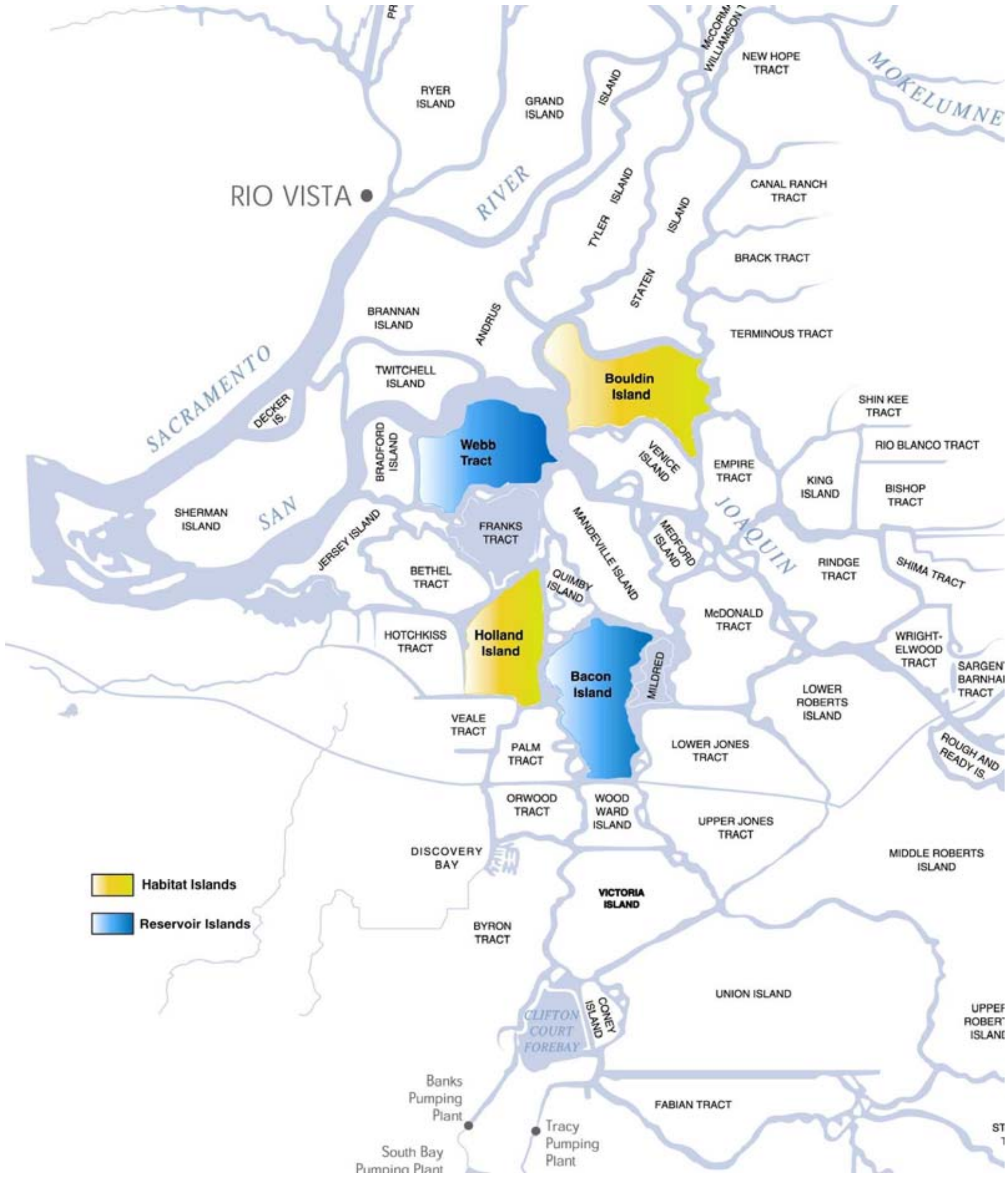


Plate 7 – Location Map of Delta Wetlands Project Storage and Habitat Islands

Plate 8 – Collapsed screen (Lakos Plum-Creek Design) following failure of cleaning system and excessive debris. Screen was not designed for easy removal and did not have monitoring features to turn off pumps.

Appendix C

Appendix C: List of Tables and Figures (as provided by DWR)

TABLE 1
Webb Tract Facilities

Table 1: Webb Tract Facilities

Facility	Pump Station	Siphon Station	Siphon Station
Location	Sta 190+00	Sta 200+00	Sta 330+00
Equipment	(32) pumps @ 3,000 cfs 36" diameter pipe 36" x 120" expansion chamber 20' erosion protection rock 10 berth boat dock 50' x 100' maintenance facility	(16) siphons @ 1,375 cfs 36" diameter pipe 7'-9" x 25'-6" fish screen 10 berth boat dock 50' x 100' maintenance facility	(16) siphons @ 1,375 cfs 36" diameter pipe 7'-9" x 25'-6" fish screen 10 berth boat dock 50' x 100' maintenance facility
Dimensions	(32) pumps x 25' OC = 800' 10 berth boat dock = 180' Total pump station length = 980' Rock = 800' x 20' = 16,000 sf Footprint = 980' x 60' = 58,800 sf	(16) siphons x 40' OC = 640' 10 berth boat dock = 180' Total siphon station length = 820' Footprint = 820' x 65' = 53,300 sf	(16) siphons x 40' OC = 640' 10 berth boat dock = 180' Total siphon station length = 820' Footprint = 820' x 45' = 36,900 sf
Pilings:	(32) pumps x (4) pilings = 128 pilings Dock = 16 pilings Total = 144 pilings	(16) siphons x (6) pilings = 96 pilings Dock = 16 pilings Total = 112 pilings	(16) siphons x (6) pilings = 96 pilings Dock = 16 pilings Total = 112 pilings

TABLE 2
Bacon Island Facilities

Table 2: Bacon Island Facilities

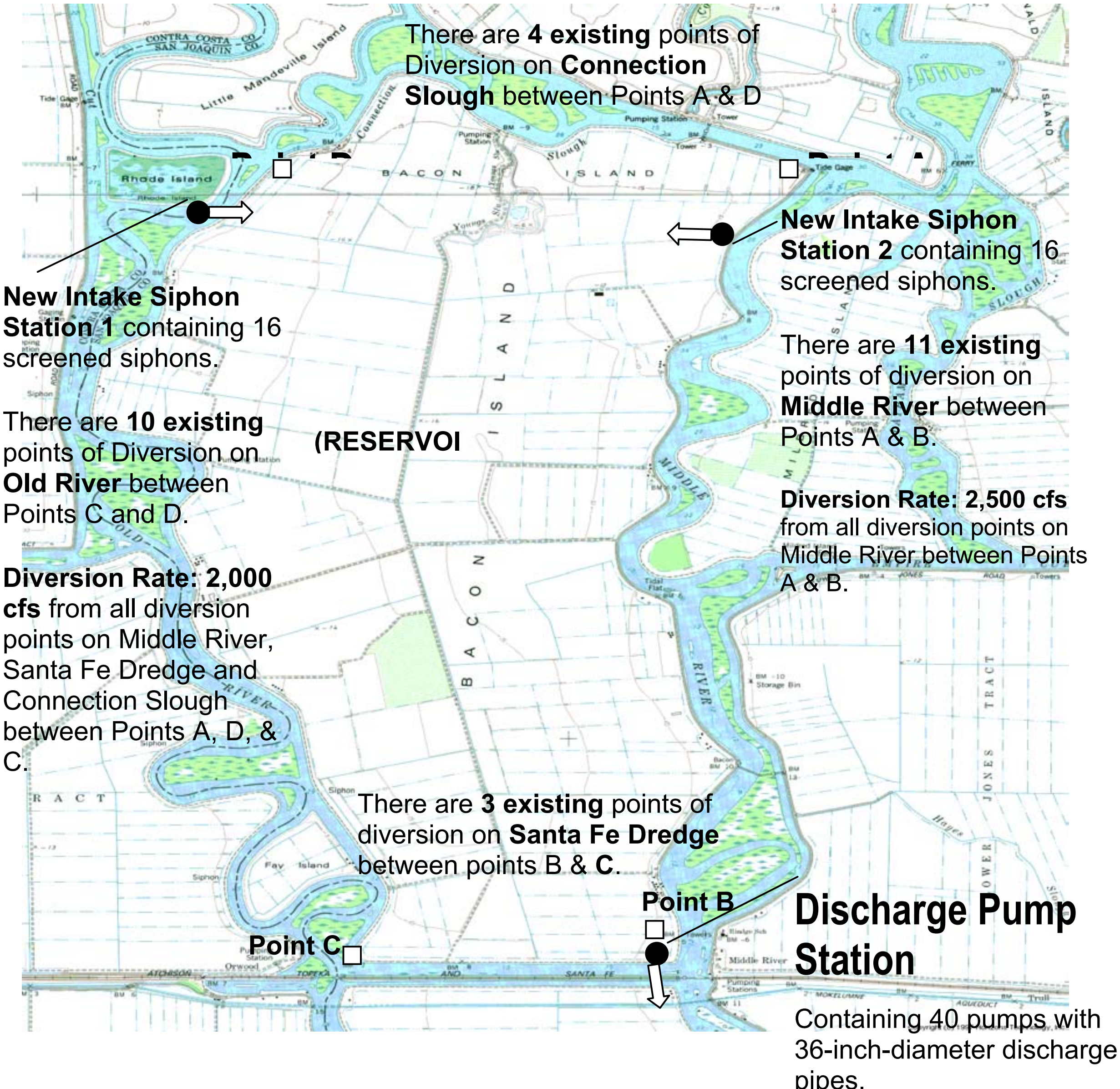
Facility	Pump Station	Siphon Station	Siphon Station
Location	Sta 700+00	Sta 180+00	Sta 360+00
Equipment	(40) pumps @ 3,000 cfs 36" diameter pipe 36" x 120" expansion chamber 20' erosion protection rock 10 berth boat dock 50' x 100' maintenance facility	(16) siphons @ 1,375 cfs 36" diameter pipe 7'-9" x 25'-6" fish screen 10 berth boat dock 50' x 100' maintenance facility	(16) siphons @ 1,375 cfs 36" diameter pipe 7'-9" x 25'-6" fish screen 10 berth boat dock 50' x 100' maintenance facility
Dimensions	(40) pumps x 25' OC = 1000' 10 berth boat dock = 180' Total pump station length = 1,180' Rock = 1,000' x 20' = 20,000 sf Footprint = 1,180' x 60' = 70,800 sf	(16) siphons x 40' OC = 640' 10 berth boat dock = 180' Total siphon station length = 820' Footprint = 820' x 55' = 45,100 sf	(16) siphons x 40' OC = 640' 10 berth boat dock = 180' Total siphon station length = 820' Footprint = 820' x 55' = 45,100 sf
Pilings:	(40) pumps x (4) pilings = 160 pilings Dock = 16 pilings Total = 176 pilings	(16) siphons x (6) pilings = 96 pilings Dock = 16 pilings Total = 112 pilings	(16) siphons x (6) pilings = 96 pilings Dock = 16 pilings Total = 112 pilings

TABLE 3
Existing Siphons

Table 3: Existing Siphons

Island	Removed Siphons	Existing Siphons (New Screens)
Webb Tract	(2) siphon - San Joaquin River (2) siphons - False River (4) siphons - total removed	(4) siphons - San Joaquin River (1) siphon - Old River (2) siphons - False River (7) siphons - with new fish screens (7) siphons x (4) pilings = 28 pilings Area = (7) siphons x 6' x 40' = 1,680 sf
Bacon Island		(10) siphons - Old River (4) siphons - Connection Slough (11) siphons - Middle River (3) siphons - Santa Fe Cut (28) siphons - with new fish screens (28) siphons x (4) pilings = 112 pilings Area = (28) siphons x 6' x 40' = 6,720 sf
Bouldin Island	(5) siphons - Mokelumne River (2) siphons - Potato Slough (1) siphon - Little Potato Slough (8) siphons - total removed	(6) siphons - Mokelumne River (3) siphons - Potato Slough (4) siphons - Little Potato Slough (1) siphon - San Joaquin River (14) siphons - with new fish screens (14) siphons x (4) pilings = 56 pilings Area = (14) siphons x 6' x 40' = 3,360 sf
Holland Tract		(3) siphons - Roosevelt Cut (3) siphons - Old River (2) siphons - Rock Slough (8) siphons - with new fish screens (8) siphons x (4) pilings = 32 pilings Area = (8) siphons x 6' x 40' = 1,920 sf
Total	(12) siphons - total removed	(57) siphons - with new fish screens (57) siphons x (4) pilings = 228 pilings Area = (57) siphons x 6' x 40' = 13,680 sf

FIGURE 1
Delta Wetlands Project Alternative – Bacon Island

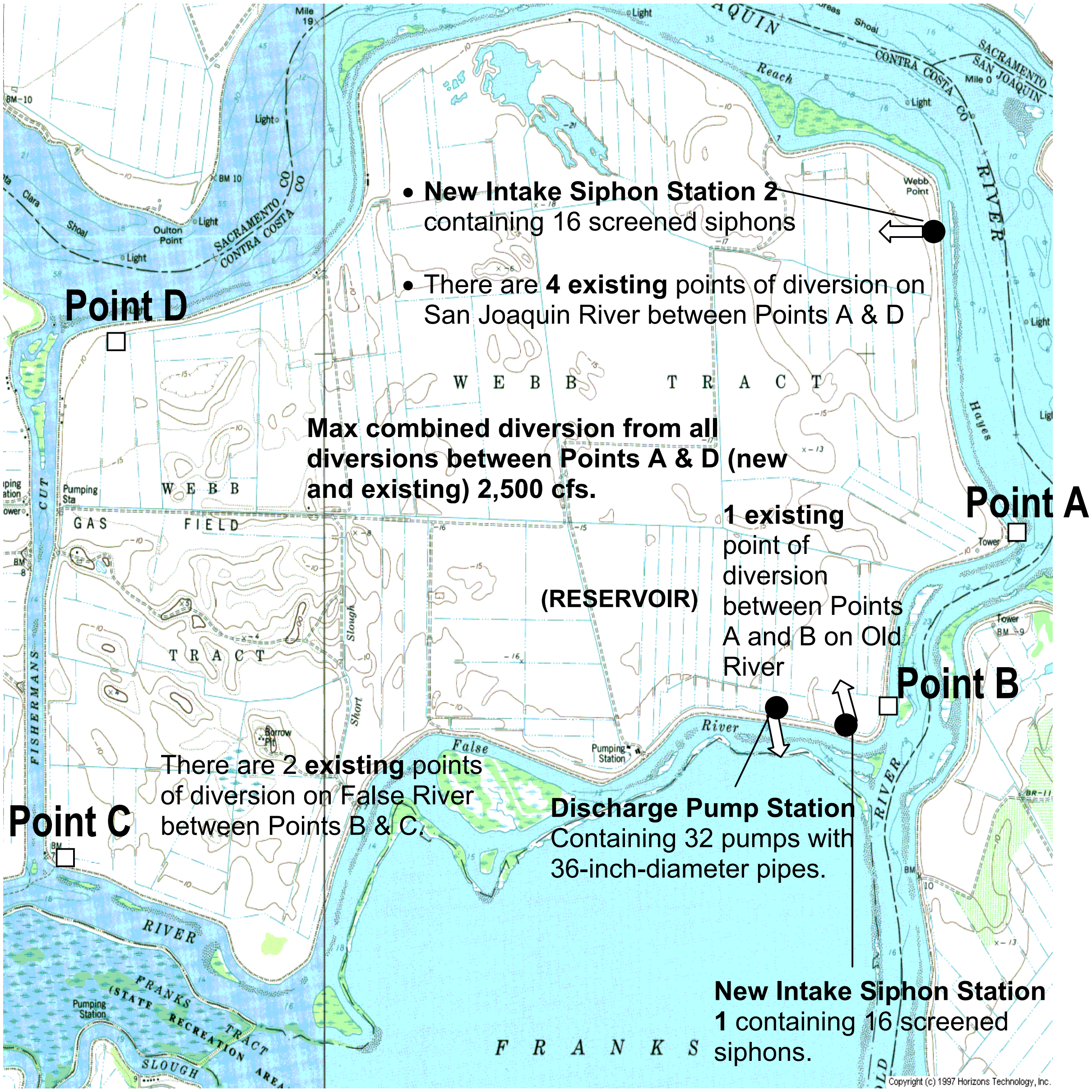


Total Project Diversions and Discharges

Diversions (all islands combined):	
Total max day	9,000 cfs*
Total ave. month	4,000 cfs*
* Habitat Island diversions included	
Discharges (all islands combined):	
Total max day	6,000 cfs
Total ave. month	4,000 cfs

IN-DELTA STORAGE PROGRAM
DELTA WETLANDS PROJECT
ALTERNATIVE 1
Figure 1

FIGURE 2
Delta Wetlands Project Alternative 1 – Webb Tract



Max combined diversion from all diversions between Points B & C (new and existing) 2,000 cfs.

Total Project Diversions and Discharges

Diversions (all islands combined):	
Total max day	9,000 cfs*
Total ave. month	4,000 cfs*
* Habitat Island diversions included	
Discharges (all islands combined):	
Total max day	6,000 cfs
Total ave. month	4,000 cfs

IN-DELTA STORAGE PROGRAM

FIGURE 2-1
Siphon Station Plan View (as proposed in Delta Wetlands Project EIR/EIS Appendix 2)

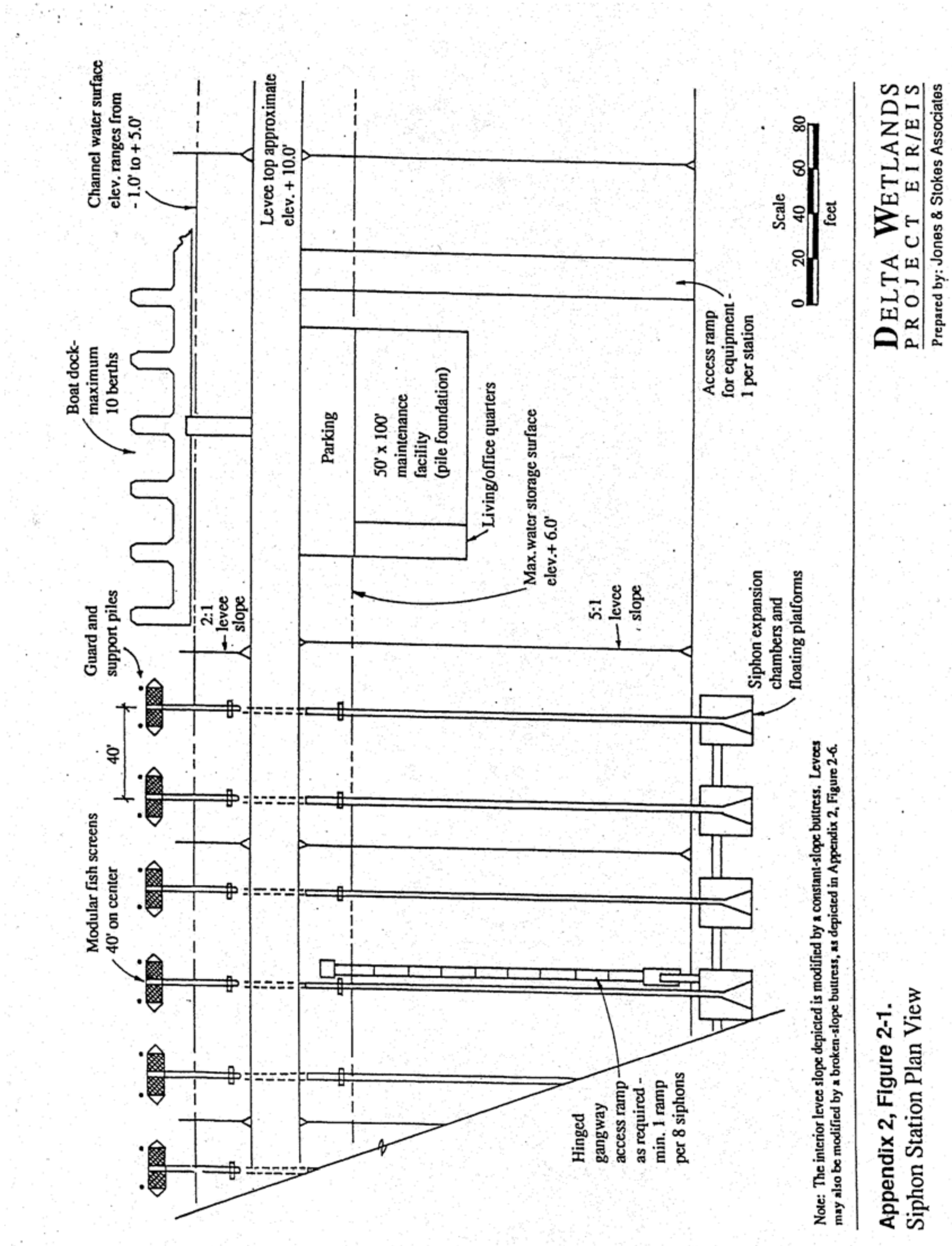
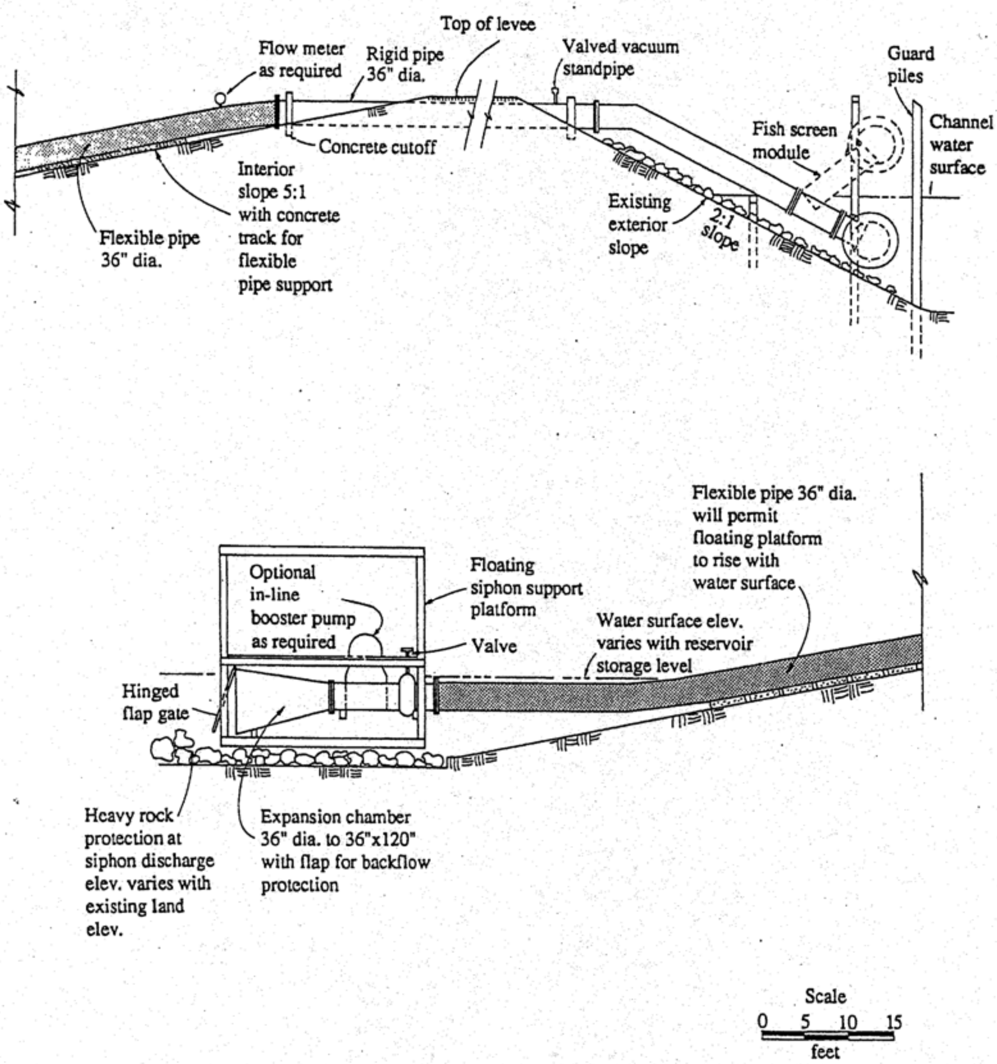


FIGURE 2-2
Conceptual Siphon Unit (as proposed in Delta Wetlands Project EIR/EIS Appendix 2)

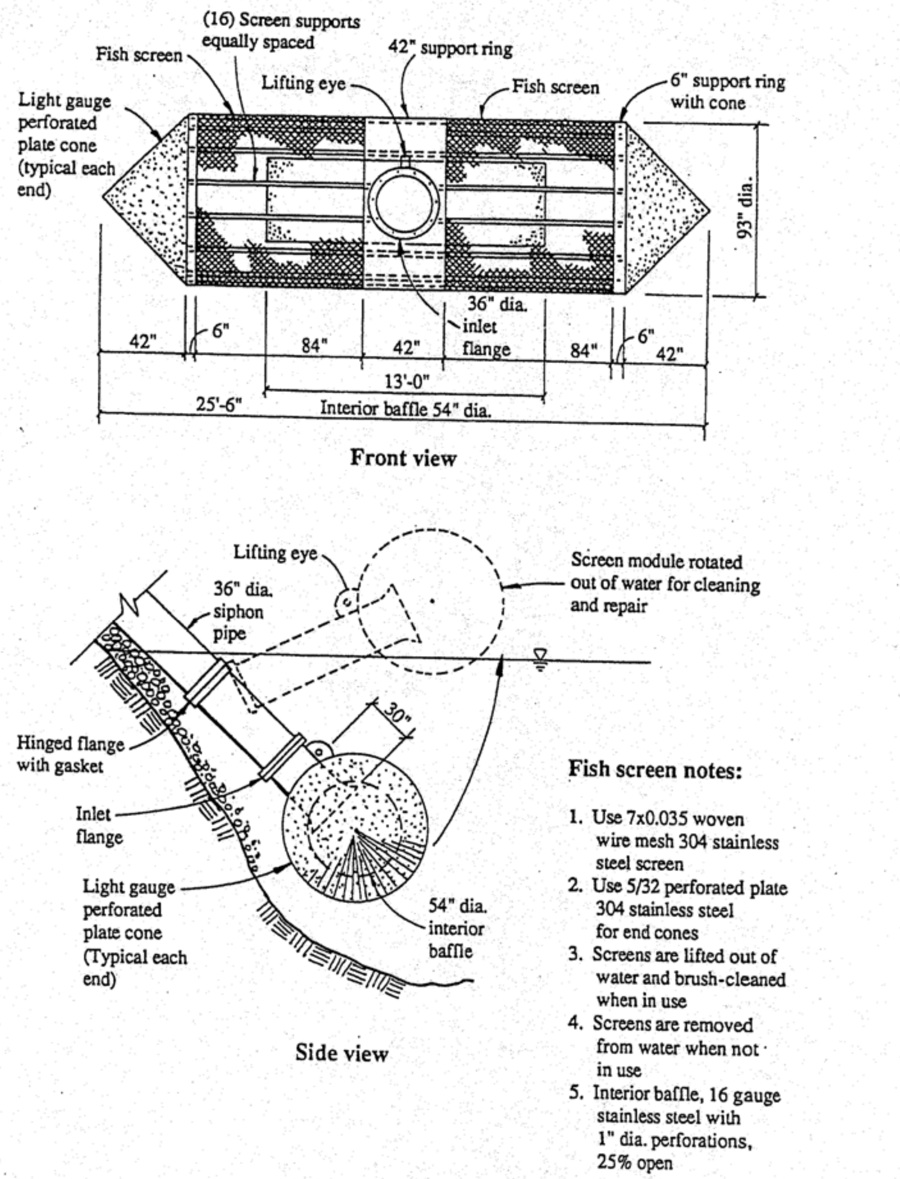


Note: The interior levee slope depicted is modified by a constant-slope buttress. Levees may also be modified by a broken-slope buttress, as depicted in Appendix 2, Figure 2-6.

Appendix 2, Figure 2-2.
Conceptual Siphon Unit

DELTA WETLANDS PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

FIGURE 2-3
Fish Screen Design (as proposed in Delta Wetlands Project EIR/EIS Appendix 2)



Appendix 2, Figure 2-3.
Fish Screen Design

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

FIGURE 2-4
Pump Station Plan View (as proposed in Delta Wetlands Project EIR/EIS Appendix 2)

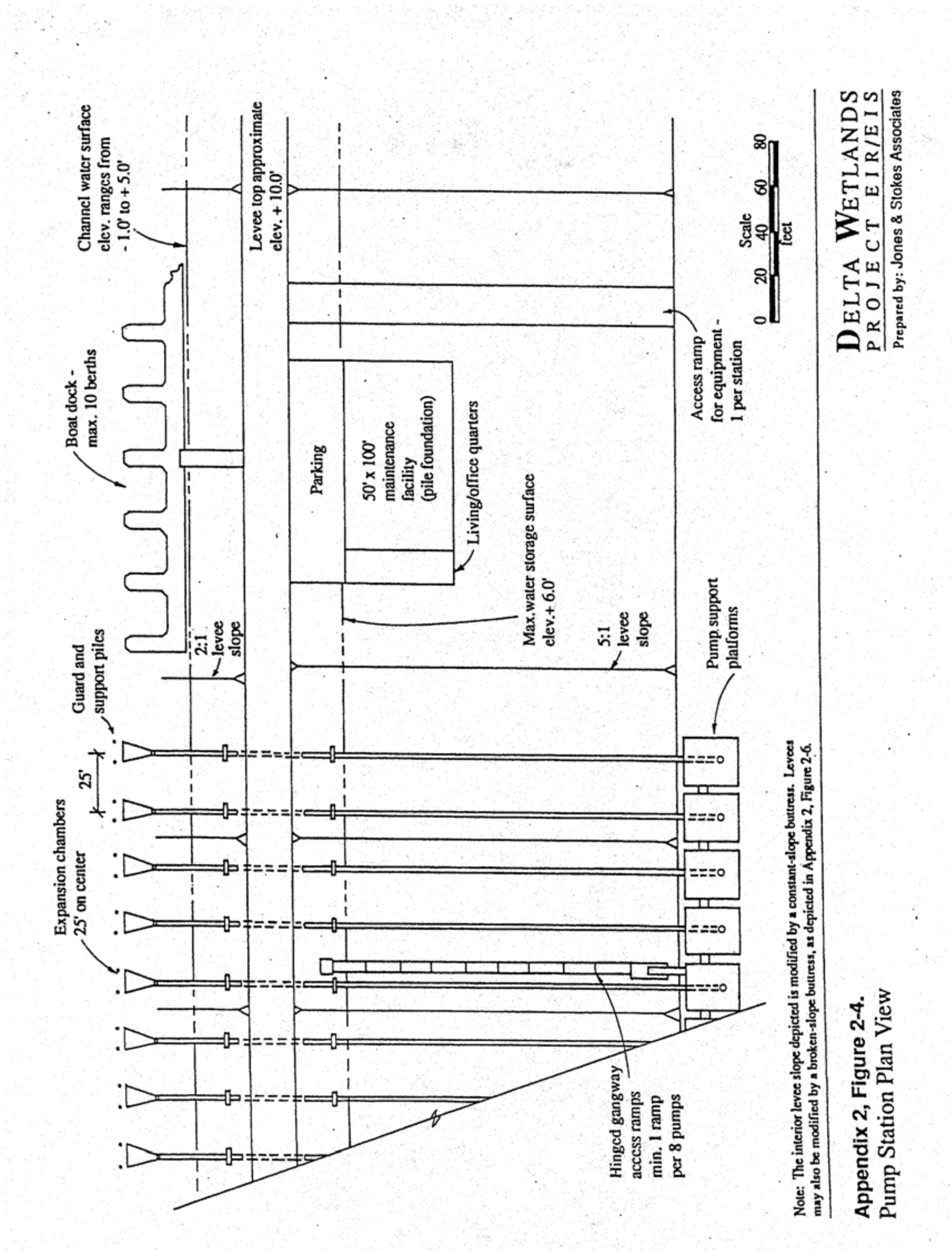
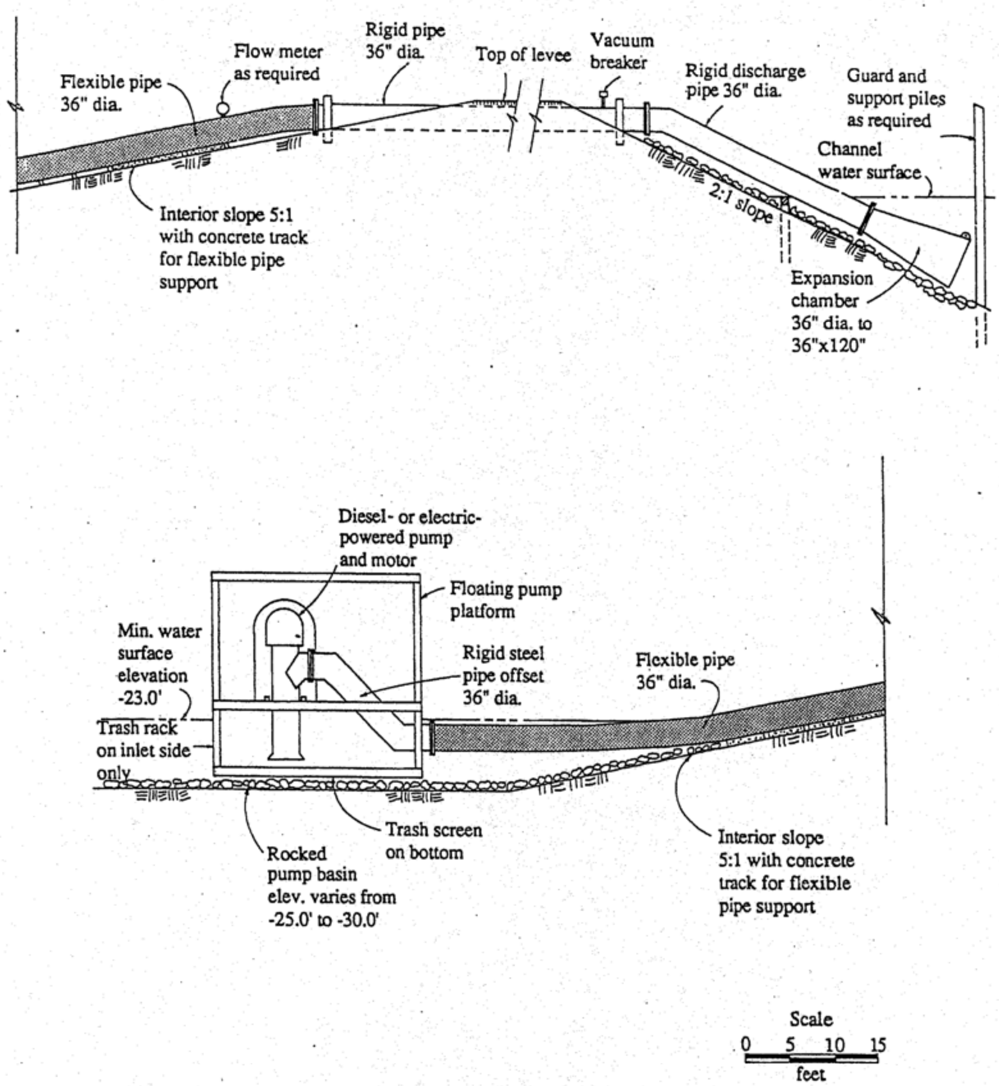


FIGURE 2-5
Conceptual Pump Unit (as proposed in Delta Wetlands Project EIR/EIS Appendix 2)



Note: The interior levee slope depicted is modified by a constant-slope buttress. Levees may also be modified by a broken-slope buttress, as depicted in Appendix 2, Figure 2-6.

Appendix 2, Figure 2-5.
Conceptual Pump Unit

DELTA WETLANDS PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

FIGURE 5

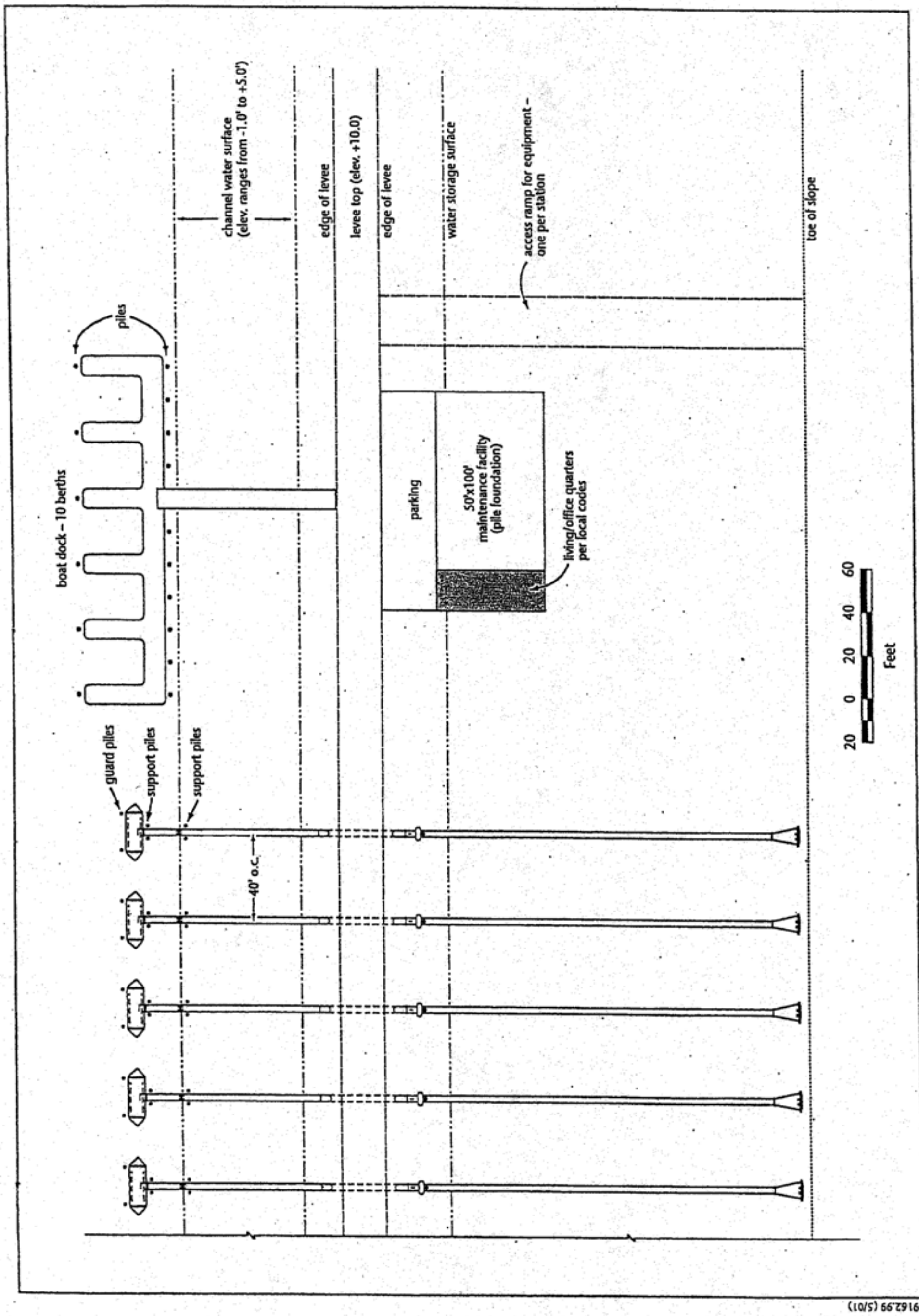


Figure 5
Siphon Plan View
May 10, 2001

FIGURE 6

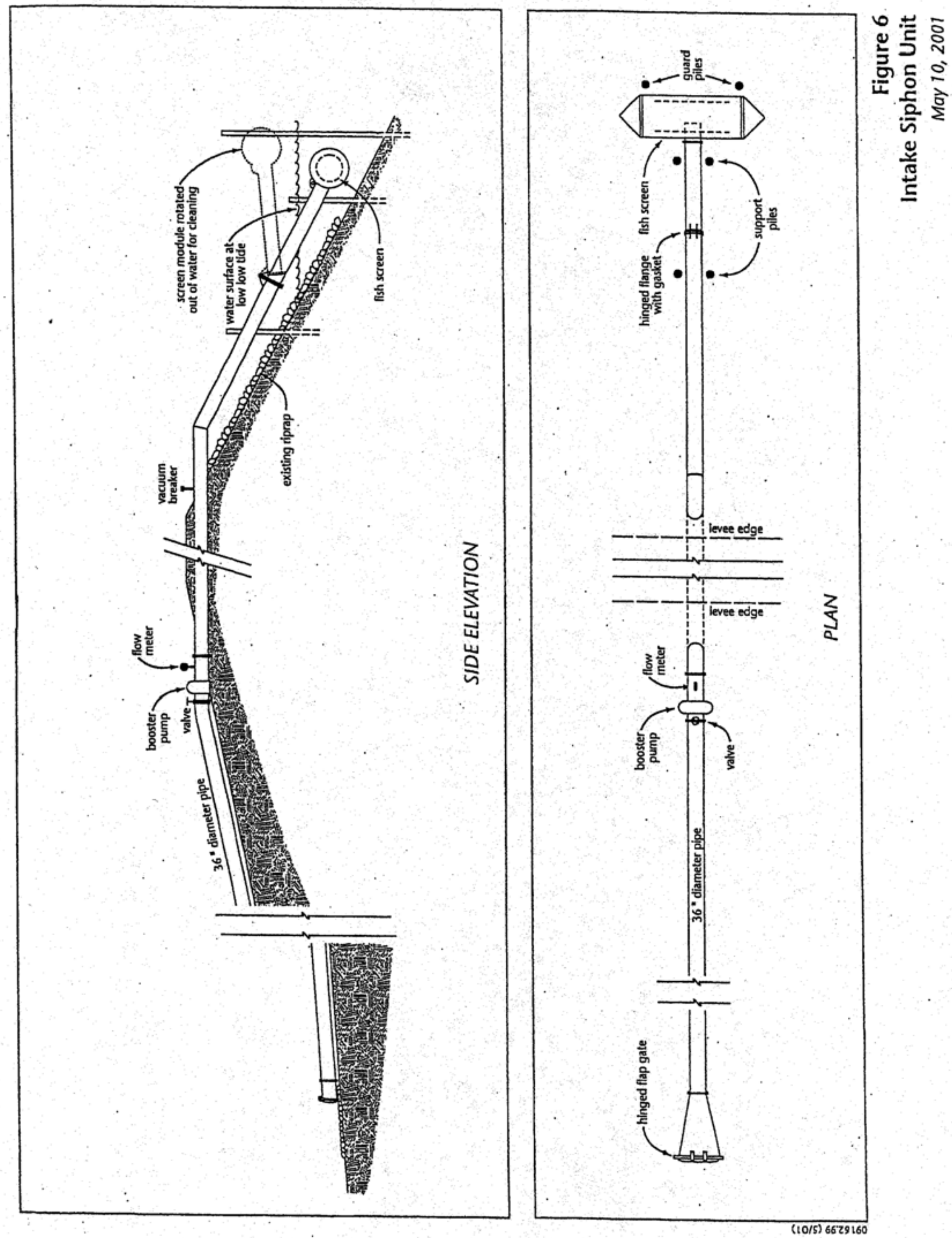

screen module rotated
out of water for cleaning
water surface at
low low tide
fish screen
existing riprap
vacuum
breaker
flow
meter
booster
pump
valve
36" diameter pipe
SIDE ELEVATION
guard
piles
fish screen
support
piles
hinged flange
with gasket
levee edge
levee edge
PLAN
flow
meter
booster
pump
valve
36" diameter pipe
hinged flap gate
Figure 6
Intake Siphon Unit
May 10, 2001

FIGURE 7

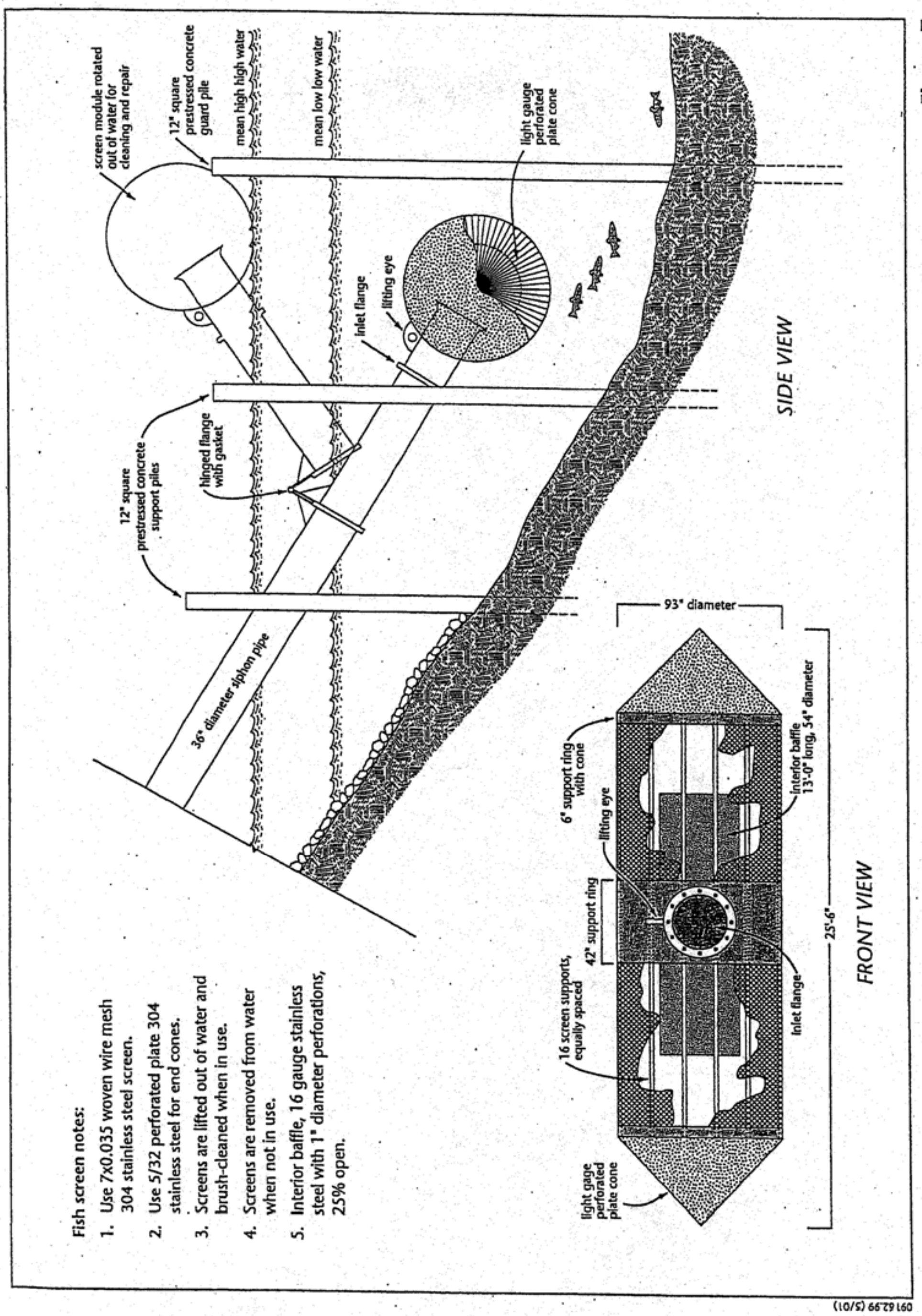

Fish screen notes:
1. Use 7x0.035 woven wire mesh 304 stainless steel screen.
2. Use 5/32 perforated plate 304 stainless steel for end cones.
3. Screens are lifted out of water and brush-cleaned when in use.
4. Screens are removed from water when not in use.
5. Interior baffle, 16 gauge stainless steel with 1" diameter perforations, 25% open.
screen module rotated out of water for cleaning and repair
12" square prestressed concrete guard pile
mean high high water
mean low low water
light gauge perforated plate cone
inlet flange
lifting eye
hinged flange with gasket
12" square prestressed concrete support piles
36" diameter siphon pipe
SIDE VIEW
93" diameter
6" support ring with cone
lifting eye
42" support ring
16 screen supports, equally spaced
light gage perforated plate cone
inlet flange
interior baffle 13'-0" long, 54" diameter
25'-6"
FRONT VIEW
Figure 7
Fish Screen Design
May 10, 2001
091.62.99 (5/01)

FIGURE 8

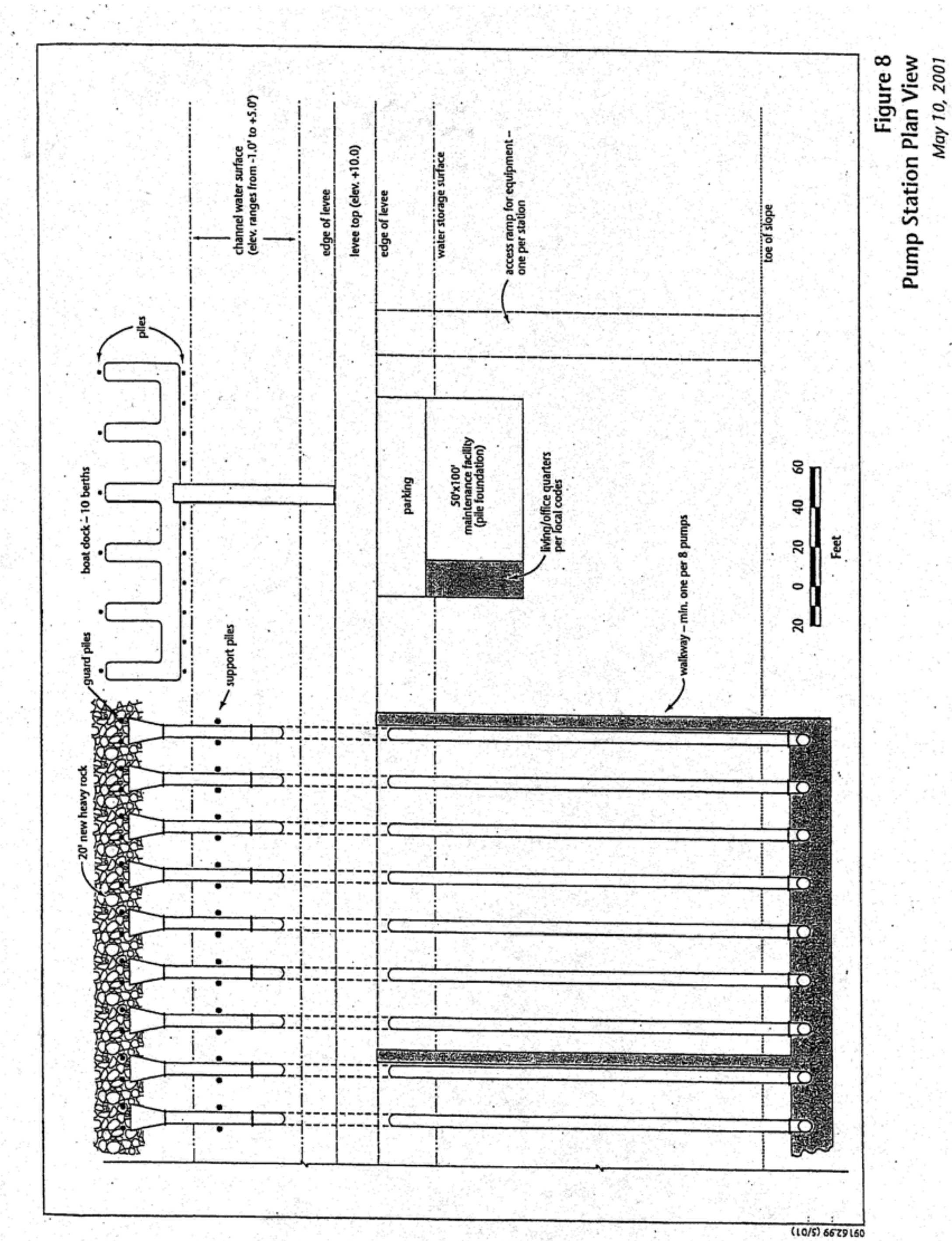
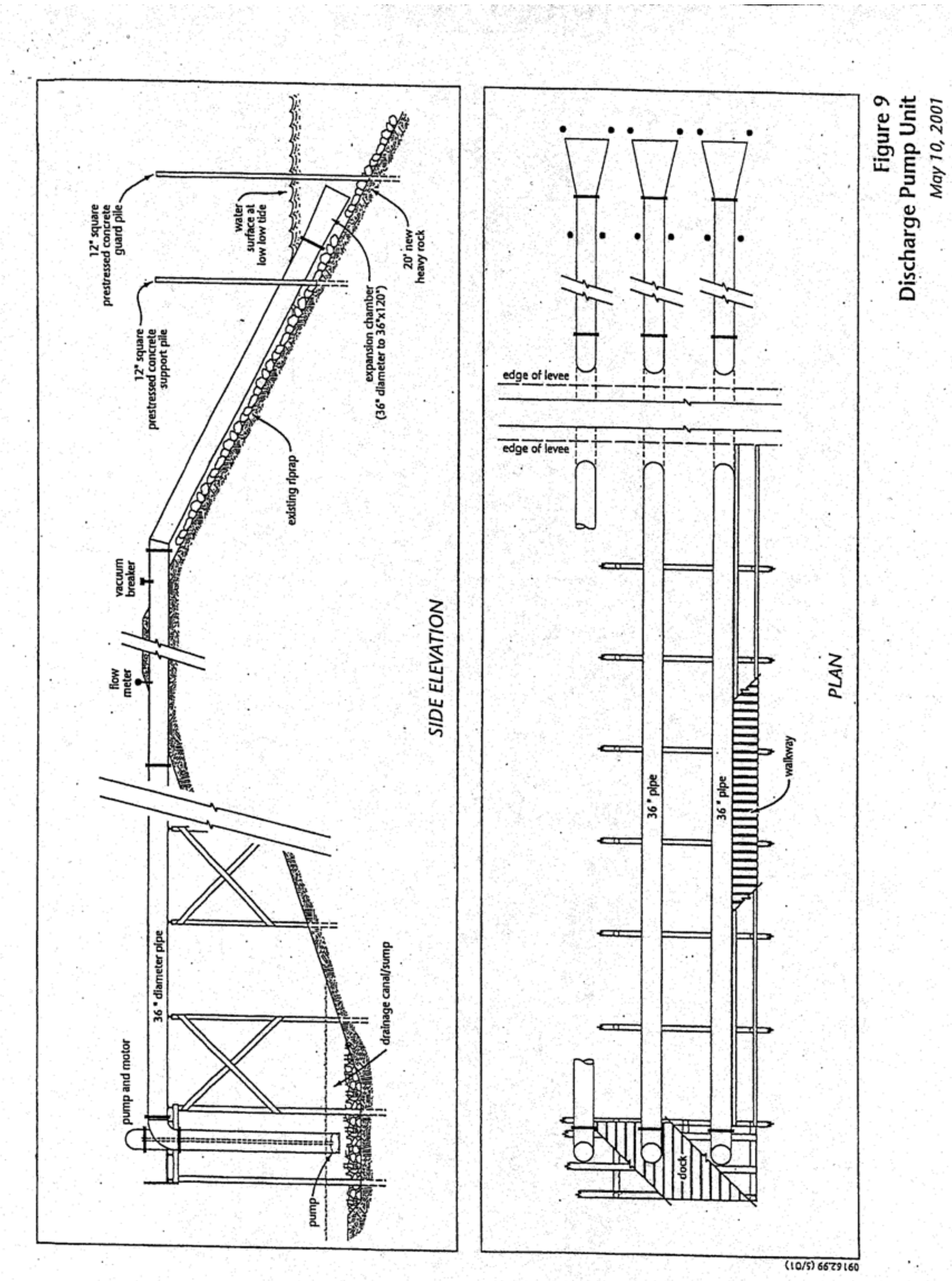


Figure 8
Pump Station Plan View
May 10, 2001

FIGURE 9


12" square prestressed concrete guard pile
12" square prestressed concrete support pile
water surface at low low tide
20' new heavy rock
expansion chamber (36" diameter to 36"x120")
existing riprap
vacuum breaker
flow meter
pump and motor
36" diameter pipe
drainage canal/sump
pump
SIDE ELEVATION
edge of levee
edge of levee
36" pipe
36" pipe
walkway
dock
PLAN
Figure 9
Discharge Pump Unit
May 10, 2001